The ERP Paradox: An Empirical Investigation of the Impact of Enterprise Systems on Operational Effectiveness

Dissertation submitted by Andrea Masini in partial fulfillment of the requirements for the degree of Ph.D. in management from INSEAD

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To my parents

Executive Summary

In spite of the increasing IT expenditures observed in many industries, the actual benefits of information technologies are still being questioned, both from a financial and an operational standpoint. Furthermore, the fundamental mechanisms through which IT systems impact productivity, and hence profitability, remain largely underexamined and are still poorly understood. There is also increasing evidence that the mere adoption of IT systems of ever increasing complexity and cost does not guarantee by itself the achievement of performance improvements. It is only when they are accompanied by the development of effective IT *capabilities* that IT investments produce operational improvements and possibly, sustained competitive advantage. However, while the importance of possessing these capabilities becomes increasingly more evident, it is less clear what the underlying mechanisms that enable their generation are – and also, whether they display a similar degree of effectiveness for companies that operate in different environmental settings.

The general purpose of this dissertation is to shed further light on this controversy and to further clarify whether and how the adoption of complex information technologies contribute to the generation of business value.

In the first section of this work we propose and test empirically a general model of IT-driven performance that, by using Enterprise Resource Planning systems as a representative example, explains why, through which mechanisms and under what environmental conditions the adoption of IT innovations may affect operational excellence. Drawing from the resource-based view of the firm we first identify dynamic capabilities (i.e. the ability to rapidly reconfigure organizational routines to address dynamic markets) as a key mechanism through which business organizations achieve operational effectiveness. Second, we observe that the adoption of an ERP system always interferes with the knowledge evolution cycle that support the genesis and the development of these capabilities and we examine how the structural properties of the system alter the characteristics of the adopter's organizational routines. Third we posit that the structural impact of ERP may be amplified or attenuated by two moderating factors: the attributes of the firm's bureaucracy and the degree of turbulence of the firm's operational environment. The analysis of a sample of ERP adopters worldwide supports our framework and it indicates that the changes in operational indicators of performance observed across adopters are best

explained by modifications occurred in two antecedents of dynamic capabilities: process efficiency and process flexibility. The results also suggest that firms that operate in unstable environments and that display high degree of organizational rigidity exhibit lower returns to ERP adoption.

In a second section we examine how knowledge investments contribute to the development of IT capabilities. Our underlying research hypothesis is that, as knowledge and learning investments are important determinants of operational effectiveness and as IT systems play a paramount role in enabling these activities, IT implementation strategies that entail knowledge development efforts should be also designed to spouse the specific requirements of the firm's operational environment. This part of the dissertation has two specific objectives. First and foremost it aims at identifying configurations of IT adopters that exhibit common characteristics with respect to both their IT implementation strategies (particularly in relation to the intensity of their knowledge investments) and the environment in which the companies operate. Second, it aims at examining whether and under what circumstances some configurations exhibit superior results.

The application of cluster analysis to a sample of 75 companies that adopted SAP R/3 between 1995 and 2000 uncovers four distinct configurations of ERP adopters. The results suggest that complex and turbulent environments provide greater challenges to ERP adopters than stable and simple ones, and also that these challenges can be effectively addressed by means of appropriate knowledge-intensive strategies that privilege articulation efforts. They also highlight that, whereas strategies based on limited knowledge investments are still effective in steady environments, where the relative stability of the underlying reference system renders repeated adjustments based on a trial and error strategy still possible, they become intrinsically hazardous when the competitive landscape shifts continuously and unpredictably.

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Foreword

No exercise could be more difficult than summarizing in a few sentences the intellectual challenges, the personal struggle and the great human experiences that made the completion of this work possible.

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The many years spent at INSEAD would have certainly not been so special without the friendship of my colleagues from the Ph.D. program and from the various research centers in the school. Interacting with all of them was a splendid human experience, but also a true intellectual challenge that provided me with countless learning opportunities.

This list would be too long to mention everyone, but I would like to spend at least a few words to thank Roland and Francesco for the many (perhaps too many...) hours that we spent climbing and jogging together in the forest of Fontainebleau. Whether these strenuous training sessions accelerated or delayed this dissertation remains an open question. What cannot be questioned, however, is that they enormously contributed to its completion. First, because they released pressure from the author's neurons - worn out by too many hours of hard Ph.D. deskwork. Second, because the stimulating discussions that we had while wearing out our fingertips on utterly desperate climbing problems or while panting along the many trails in the forest sharpened my academic thinking and helped me acquire the necessary motivation to complete this endeavor.

A particular thank must also go to all special friends whose personal life trajectory has crossed mine in the past few years, and who have been patient enough to bear the ever-changing mood of a doctoral student. This work is also their achievement.

But above all, I want to emphasize that completing this program would have never been possible without a strongest support and a continuous encouragement from my parents, to whom this dissertation is dedicated.

Chapter 1

The IT productivity paradox

1.1 Introduction[1]

IT systems are among the most fundamental assets of today's enterprises: they constitute the technological pillar that supports all the organizational processes through which the firm responds to changes in its external environment (Mendelson, 2000). Not surprisingly, many business organizations that are confronted with the ever-increasing turbulence of their operating markets, massively invest in information systems, either through the adoption of new technologies or through the upgrading of existing ones.

A well representative example of this trend is provided, for instance, by the spectacular diffusion of Enterprise Resource Planning systems (ERP[2]) that occurred in almost every industry in the past few years. With an estimated turnover of about $84 billion in 2002[3] and growth forecasts that continue to increase, the ERP "ecosystem" is one of the most important phenomenon in today's economy and, certainly, the one that best represents the magnitude of IT investments undertaken by modern business organizations.

However, in spite of these increasing expenditures, the actual benefits of IT innovations are still being questioned, both from a financial and an operational standpoint. The academic research that has focused on the relationship between IT investments and firm performance has produced mixed findings and contradictory results (Morrison and Berndt 1990; Strassmann 1990; Brynjolfsson 1993, Nolan 1994). Similarly, large and mostly unexplained performance differences are often observed across ERP adopters, even for companies that operate in the same industry and that use systems from the same vendor (Mabert, et al. 1999; Mabert et al., 2003; Umble et al., 2003). Quite interestingly, rather then being reduced, these differences have been amplified by the advent of the new generation of e-systems, which exert their impact far beyond the mere firm's boundaries and affect the relations that a business organization entertains with its whole network of suppliers and customers.

[1] We gratefully acknowledge Dr. Orestis Terzidis and Dr. Klaus Dieter Gronwald from SAP AG for their support and assistance throughout the development of this project.

[2] Throughout the paper we use interchangeably the acronym ERP or ES (for Enterprise Systems).

[3] Value estimated by the Boston-based consulting firm AMR Research in 2001.

Thus, whereas on the one hand there is growing anecdotal evidence that the performance of a firm may be significantly influenced by the intensity of its IT investments, and while many firms continue to engage themselves in IT projects of increasing cost and complexity, several important facets of this phenomenon remain poorly understood. First and foremost the mechanisms through which IT innovations affect the value-creating process of the firm are still loosely defined and lack solid theoretical grounds. Second, the fact that adopters of similar technologies often exhibit profoundly different results suggests that it is also unclear whether and how the external environment in which the firm operate and its organizational architecture influence these processes. Finally, it is also unclear whether the ultimate impact of an IT innovation is directly due to the technology "per se" or – as more recent research seems to suggest (Bharadwaj, 2000) - to the idiosyncratic IT capabilities that are developed by the adopter during the implementation of the system.

Besides being interesting research questions "per se", these are issues of fundamental practical relevance for the business community, as managers are constantly faced with the challenge of designing and implementing IT systems of ever-growing cost[4] and complexity, often without being able to assess if, how, and when they will generate adequate returns. Furthermore, - as a consequence of the fact that IT systems are recognized to "provide cost-effective functionalities for building knowledge platforms through systematic acquisition, storage and dissemination of organizational knowledge (Purvis et al. 2001, p. 117) and of the fact that knowledge and learning are increasingly recognized as a primary strategic resource for organizations (Prahalad and Hamel, 1990; Prahalad and Hamel, 1994; Kogut and Zander, 1995) - devising successful IT strategies becomes a true competitive imperative with strategic implications.

The general objective of this research is to contribute to this debate and to shed further light on the relationship between IT innovations and operational effectiveness. To this end we subdivide our contribution into two general parts. First we aim at developing a general theoretical model which, by linking organizational theory and the resource based view of the firm – explains *why*, *through which mechanisms* and

[4] As an example, a survey of 479 US manufacturing firms indicates that for an "average" firm the cost of implementing an ERP system can be as large as 5% of its annual turnover. However, it can be much larger (up to 14% of annual turnover) for small enterprises (Mabert, Soni et al. 1999).

under what environmental conditions the adoption of complex information technologies may improve the operational effectiveness of a business organization. Second, mindful of the fact that the ultimate impact of an IT innovation may be significantly influenced by the approach adopted during its configuration, we also attempt to determine whether different implementation strategies exhibit different degrees of effectiveness for organizations that operate in different competitive environments and that display antithetical organizational architectures.

In the remainder of this chapter we review the relevant literature on the topic and we precise the main research questions that we wish to address.

1.2 The IT productivity paradox

As a consequence of the spectacular growth of IT investments and of the anecdotal evidence that revealed contradictory results about the actual benefits produced by these investments[5] management scholars have recognized the need to analyze in a more rigorous fashion the relationship between IT adoption and performance of business organizations both at the financial and at the operational level.

Early research on the topic has examined whether a direct correlation could be identified between the intensity of IT investments and aggregated measures of financial performance, such as ROI, ROS or ROA. These studies produced mixed findings. Quite surprisingly some results suggested that investments in IT innovations could be either ineffective or even exert a negative impact on performance (Morrison and Berndt 1990; Strassmann 1990; Nolan 1994), and gave rise to what a felicitous expression named the "IT productivity paradox". Conversely other studies supported the paradigm that considered IT excellence as an important source of profitability (Brynjolfsson 1993; Lichtemberg 1995; Hitt and Brynjolfsson 1996).

In an attempt to shed light on this controversy, scholars have recently pointed out the inadequacy of aggregated accounting measures to evaluate all the tangible and intangible benefits of IT innovations, especially because of the problems that occur when one attempts to control for other possible sources of firm profit. Among the alternatives that have been proposed to overcome this limitation, (Bharadwaj,

[5] For a more comprehensive overview see, for instance, the discussion in (Brynjolfsson 1993) and in (Hitt and Brynjolfsson 1996).

Bharadwaj et al. 1999) replaced traditional accounting measures with a market-based variable (Tobin's q) and reported a significant and positive correlation between this measure and investments in a diversity of IT systems, which include hardware, software and data communication systems.

Along a different line, other investigations have recognized that even market-based measures account for IT effects in a way that is by far too indirect and mediated by too many confounding factors. Thus, they suggest the impact of IT be examined with respect to what we will later refer to as "operational improvements". These are improvements in factory-level and more operations-oriented measures of performance, such as manufacturing lead-time, inventory turns or waste rates. However, even these analyses have produced contradictory results, thus calling for further and more specific research on the topic. For instance, (Upton and Mcafee 1998) report that - by destroying one of the most important sources of know-why within the firm - the introduction of computerized machines in a paper mill was the primary responsible for the occurrence of severe quality problems in the manufacturing unit. (Utpton and McAfee, 2000) analyzes the adoption of Enterprise Resource Planning in a computer assembly facility and observes that– after an initial performance decrease due to post-implementation adjustments – the introduction of this technology did contribute to increase the productivity of the unit.

In one of the few attempts to shed light on the *mechanisms* through which IT affects productivity, (Brandyberry, Rai et al. 1999) finds that the adoption of several types of CIM systems is positively associated with process integration and administrative intensity, but that it has negative effects on market flexibility. Thus, the overall impact of this technology on performance is implicitly expected to be either positive or negative, depending on whether the firm derives its main sources of profit from administrative efficiency, process excellence or market-oriented flexibility.

Finally, a different stream of research on IT innovations that require long implementation processes has focused on project management issues. These studies typically investigate the impact of organizational variables on the success of the implementation process "per se" (i.e. on the extent to which the focal IT innovation is implemented on time, within budget and in line with the adopter's expectations) (Akkermans and van Helden, 2000; Mandal et al., 2003). Although studies of this nature often provide thorough insights about the driving phenomena that cause the adoption of a complex IT project to succeed or fail, they typically neglect to examine the business consequences of the innovation during its actual operational "life".

Needless to say, albeit important, the success of the implementation process "per se" is not the ultimate objective of an IT project. This is just a milestone on the road towards the achievement of operational excellence and, hopefully, improved business performance. Thus, the question naturally arises about whether technical project success is also a determinant of operational excellence and business success, and about whether the same variables that affect the first outcome also influence - directly or indirectly – the second one.

1.3 From IT adoption to the development of IT capabilities

The research on the IT productivity paradox briefly summarized above has provided ample evidence that the mere adoption of IT systems of ever increasing complexity and cost does not guarantee – by itself, the achievement of performance improvements. Conversely, researchers becomes increasingly aware that it is only when they are accompanied by the development of effective IT capabilities that IT investments produce operational improvements and – possibly, sustained competitive advantage (Markus and Benjamin, 1996) (Bharadwaj, 2000). However, while the importance of developing IT capabilities becomes more and more evident, it is still not clear how they can or should be generated, both from a practical and a theoretical standpoint.

From a practical standpoint, organizations that renovate or update their IT infrastructure are confronted with difficult choices that entail fundamental trade-offs and -- hence -- often hesitate among a variety of possible strategies, none of which has yet been proven to be generally superior (Robey and Ross, 2002). For instance, while some firms value the possibility to profit from IT projects to streamline their business processes or to prompt organizational changes, others stress that this strategy is potentially dangerous, because it is extremely costly, it requires important resources and it necessitates long implementation processes with uncertain outcomes. On the other hand, these same organizations also recognize that - whilst accelerated development strategies are typically less expensive and entail lower risks, they also reduce learning opportunities and prevent a firm from developing specific competences in the IT domain.

This uncertainty about the effectiveness of different IT strategies is also reflected at the theoretical level. While researchers have recently recognized the role of IT capabilities and have provided an attempt to portray their characteristics (Bharadwaj, 2000), they have often neglected to specify the mechanisms that permit their generation and, also, generally overlooked the question of whether different approaches to IT implementation display the same degree of effectiveness for firms that exhibit different operational and organizational needs. These are important shortcomings. First, because the mere description of IT capabilities is not a sufficient condition to guarantee their actual development. Second, because recent studies that have re-examined the relationships between strategy, organizational structure and management processes have challenged the notion of "single best practice" (Atuahene-Gima and Ko, 2001) and have suggested that similar strategies, organizational models and – by analogy, similar IT implementation patterns may produce different results in different environmental settings (Brown, 1994;Brown and Magill, 1998).

This generalized lack of knowledge about the mechanisms that subsume the development of IT competences is also due to the fact that most of the existing studies on IT implementation have often limited their analysis to the mere project management or to the technical domain (Jiang et al., 2001), without addressing the more complex issues of how alternative IT strategies may affect the knowledge-integration function that these systems perform or their contribution to the distribution of cognitive activities in the firm (Boland et al., 1994).

On the other hand, scholars who have examined the question of how learning and knowledge integration may contribute to the generation of organizational capabilities and competitive advantage have studied these phenomena in relation to a variety of business situations: mergers and acquisition (Zollo, 1998; Zollo et al., 2002), strategic alliances (Inkpen and Dinur, 1998; Kale, 1999), manufacturing processes (Carrillo and Gaimon, 2000; Lapré et al., 2000), but they have not applied this perspective to the information technology area.

As a consequence, firms confronted with the challenge of an IT implementation often lack solid theoretical grounds to design and deploy effective strategies in this domain. As recognized by the partner of a large IT consulting firm, even IT consultants often "recommend specific approaches to IT implementations without a solid understanding of the underlying phenomena that may render them effective or inappropriate for the particular case at hand".

1.4 An emerging picture and research questions

The picture that emerges from the above discussion suggests that there is still a lack of robust theoretical understanding of the mechanisms that enable firms to increase operational effectiveness and generate business value through IT investments. Rather than clearly indicating the existence of a direct and univocal link between IT innovations and performance or productivity, the research conducted so far has emphasized that:

1. The equation "IT innovation = performance" is too simplistic and does not hold generally. IT investments do have an impact on the performance of a firm, but this impact may be either positive or negative, depending on the measure adopted, the industry analyzed and the type of IT system considered. Thus, a contingency approach seems more appropriate to address the phenomena of interest, especially at the operational level;
2. The fundamental mechanisms through which IT systems impact productivity and profitability remain largely underexamined and poorly understood (i.e. there is a lack of robust theoretical explanations for the phenomena observed);
3. It is not appropriate to analyze under the same umbrella IT systems that are fundamentally different and whose impact on organizations is exerted through different mechanisms;
4. Little is known about the internal organizational contingencies or the external environmental conditions that may amplify or hamper IT effectiveness. That is, little is known about the conditions under which a particular IT system becomes an effective performance driver or a severe handicap for the achievement of both operational improvements and superior business performance. In turn, this implies that very limited managerial insights can be derived from the results obtained so far;
5. It is still unclear whether soundly designed implementation strategies can always guarantee the generation of IT capabilities regardless of the particular operational environment where the rollout takes place and if these strategies must be

specifically adapted to the different operational and organizational contingencies that may arise.

6. Most of the few studies that provide causal explanations for the phenomena investigated are typically restricted to a single firm. Thus, their results may be difficult to generalize beyond the boundaries of the specific organization studied;
7. Observations 2, 4 and 6 above are particularly true for enterprise systems, which, in spite of their cost and of their potential impact, have only recently received attention by the academic community.

These observations constitute the point of departure of our investigation. They suggest that there is a real need for a more general theory of IT-driven performance, which, after distinguishing across different categories of IT innovations, explains why, through which mechanisms and under what environmental conditions the adoption of these technologies may produce operational improvements and, possibly, contribute to the generation of economic profit.

Noting that operational effectiveness is typically a primary driver of business performance (Wheelwright and Bowen 1996) and following a recent call for more firm-specific and process-oriented research on the impact of IT systems (Barua, Kriebel et al. 1995; Mooney, Gurbaxani et al. 1995), in the reminder of this work we aim at explaining the large differences observed across IT adopters in key performance indicators at the business process level. More specifically, we plan to address the following research questions:

- Question 1: what are the mechanisms through which the adoption of an IT innovation affects operational effectiveness? Are these mechanisms simply related to an improvement of the information management activities inside the firm and to a better utilization of the company resources or do they involve cognitive and behavioral phenomena that initiate a process of organizational learning?

- Question 2: Is the impact of IT adoption contingent to the specific organizational and industry environment in which the adopter operates?

- Question 3: What are the phenomena and the cognitive mechanisms that subsume the generation of IT capabilities? Do they display the same degree of effectiveness in different organizational and operational contexts?

For purposes of consistency we restrict our investigation to a specific class of information technologies (Enterprise Resource Planning systems), which is particularly representative of the phenomena we wish to study. Also, we ground our analysis on the actual experience of a group of companies that have adopted a specific IT product (SAP R/3) in the past decade.

1.5 Scope of the research

1.5.1 A taxonomy of IT systems

In the previous paragraphs we have argued that some of the discrepancies across studies that examine the relationship between IT impact and performance may be due to the fact that they aggregate under the same umbrella IT systems that are fundamentally different. In its broadest sense, the term information technology refers to generic computer-based systems that support the basic processes through which a firm produces and delivers to the market products or services. However, in practice IT systems include a set of technologies (hardware) and applications (software) of a great diversity, which are also expected to impact the performance of a firm through different mechanisms and at different levels.

Accordingly, to address the research questions highlighted above one should first distinguish among different classes of IT systems, restrict the analysis to *homogeneous clusters* of technologies that exhibit common characteristics, and only then analyze in detail their functionalities and their impact on the processes that guarantee the profitability of the host organization.

Following (Swanson 1994), we classify IT systems with respect to their business impact, i.e. the extent to which they affect the three fundamental profit centers of an organization: the IS core, the administrative core and the technical core. *Functional* IT innovations are "pure" information technologies whose impact is fundamentally limited to the IS department. *Administration-integrated* IT innovations are systems whose impact also extends to the administrative core but that do not have fundamental technological implications. Finally, *integral*[6] IT innovations are

[6] The three classes are named type I, type II and type III innovations in Swanson's taxonomy.

technologies that affect all the three cores of the host organization that modify its entire business architecture and that also bring competitive advantage to their early adopters. Furthermore, we also observe that these technologies usually display a fairly long "life cycle", which is roughly subdivided into two major temporal phases, namely: the implementation (where the system is designed and configured to match the adopter's requirement) and the "live" phase (where it is actually used to support the firm's daily operations). The latter property plays a fundamental role, as it is precisely during the configuration phase that the system acquires some of the distinctive features through which it exerts its impact on the ultimate business success of the organization.

Together, these characteristics render integral IT innovations fairly unique and determine the mechanisms through which they affect the value creating mechanisms of a firm. For their importance and for the magnitude of their expected impact on the degree of success of an organization these technologies are the most appropriate to highlight the phenomena that we want to address. Thus, we restrict our analysis to this class of systems and we focus specifically on its most representative example: Enterprise Resource Planning systems.

1.5.2 Narrowing the focus: ERP systems

Enterprise Resource Planning systems are the most typical archetype of integral IT innovations and, possibly, the most representative type of information technology appeared on the market in the past few years. They are large computer systems that – through a common database - integrate different application programs in many (possibly all) functions of the firm: accounting, sales, manufacturing, finance and human resource management (Jacobs and Whybark 2000).

Besides the important technical benefits they produce (increase of accuracy, homogeneity and timeliness of information within the organization), these systems also require a major re-engineering of the firm business process during their implementation. From a logical perspective, an enterprise system is organized around the so-called "best practices" or "reference models" (Keller and Teufel 1998). These are generic built-in *process templates* contained in the software library that represented the "state of the art" when the system was conceived or updated by its designer. Loosely speaking, a best practice suggests an organization what the optimal process configuration and the most efficient resource allocation scheme(s) are for the execution of a particular task.

As a consequence of this particular structure, a firm that adopts an enterprise system is forced to analyze its business model, to map and *codify* its processes and, possibly, to re-configure them (either to eliminate possible bottlenecks that have emerged or simply to better match the process templates contained in the software library). This architectural reorganization is *de facto* a major business re-engineering process and – as we will conjecture – it is the major responsible for the performance changes caused by the adoption of the system.

The choice to focus on Enterprise systems for our study was motivated by a number of reasons. First and foremost from a research viewpoint, this technology offers an excellent opportunity to address the questions we have highlighted above. By virtue of its degree of penetration in the core processes of a business organization, an ERP implementation is likely to have a deeper and therefore easier to detect impact than the adoption of an "average" IT system.

Second – but certainly not less important, the choice was motivated by the relevance that the ERP phenomenon still has for the business community. Despite the current economic slowdown, Boston-based AMR Research still estimated a total turnover of $ 84 billion for the ERP ecosystem (software vendors, specialized consultants) and predicted that the demand for these applications to increase at an annual rate of around 30% in 2003. However, as suggested by academic journals and the popular press – which report both horror stories (Bancroft and others, 1998; Laughlin. S.P., 1999) and spectacular successes (Umble et al., 2003), there is still conflicting evidence about what ultimately determine an ERP project to succeed or fail. As the cost and the risks of an ERP implementation still remain particularly high – most potential adopters strive for sound and theory-driven recommendations that may help them survive their enterprise projects and reduce the payback time to more acceptable levels[7]. With the saturation of the large company market this need is becoming increasingly more stringent, as ERP vendors aggressively target small and

[7] Despite the efforts made by most software vendors to reduce the length of ERP implementation projects, actual payback times for this technology remain significantly high and may be as long as 6 years (Stein, 1999).

medium firms, for which the costs of a project (and hence the risks of a failure) are proportionally larger[8].

Finally, a review of the academic literature on enterprise systems[9] suggests that there is still a clear need for solid empirical research that - by linking in a causal fashion the software implementation strategy to the operational consequences of the technology - examines the impact of enterprise systems from a process-oriented perspective. This knowledge gap is due to the difficulty of collecting comprehensive data that is typically encountered by researchers who want to study ERP implementations. For instance, most studies that address in detail the challenges of an ERP project at the micro level and that are reach enough to account for organizational and project-management aspects are case-based and exploratory in nature (Ash and Burn, 2003; Mandal and Gunasekaran, 2003; Umble et al., 2003). On the other hand, the more recent works that have examined the issue of ERP impact from an economic and econometric perspective (Hitt et al., 2002) – hence overcoming the limitations of a case-based approach - use data bases that are not rich enough to account for organizational and project-specific variables. As such - although they certainly shed light on the correlation between ERP adoption and productivity - they still fail to provide a causal explanation for the phenomena observed at the micro level.

1.6 Summary of the research

The general architecture of this work reflects the lines discussed above. In Chapter 2 we follow an inductive-deductive approach and we start by presenting the experience of five companies that have recently adopted an enterprise system. By identifying the principal tradeoffs and the practical problems encountered by a few representative organizations these examples offer a useful point of departure for our analysis and help relate the general theoretical questions that we wish to address to real business cases. Chapter 3 combines the above observations with management theory to construct a general framework of IT-driven profitability that will be useful

[8] For instance, in a survey of US manufacturing firms Mabert et al., (1999) found that the cost of implementing an ERP system was estimated to be around 5% of the annual turnover for the "average" company. However they also reported that this figure could be as large as 15% for smaller enterprises.

[9] See chapter 3 for a more comprehensive literature review on this topic.

to generate specific research hypotheses. Chapter 4 describes the research design and the data collection process that we have followed to test our framework, whereas chapters 5 and 6 contain the main contribution of our study. Chapter 5 focuses on the direct impact of an IT adoption. It attempts to explain the performance differences observed across ERP adopters by considering the changes that the technology produces on the cognitive mechanisms that subsume the generation of organizational capabilities. Chapter 6 addresses the issue of implementation. After recognizing that the managerial choices operated during the system rollout may attenuate or amplify the structural impact of the technology, we challenge the notion of "best practice" and we demonstrate that the development of effective ERP capabilities is idiosyncratic to the operational and organizational environment in which the system operates and to the type of knowledge investments undertaken by the firm. Finally, chapter 7 summarizes the main contributions of this work and it suggests a few avenues for future research.

Chapter 2

Exploratory Findings from the Industry Experience

2.1 Sample selection and interview structure

To anchor our analysis to real business grounds and to get a more precise understanding of the operational and organizational challenges associated with an ERP implementation we decided to start our investigation by analyzing in detail the experience of a restricted sample of ERP users. For purposes of consistency we restricted the analysis and the data collection process described in chapter 4 to companies that adopted SAP R/3, the ERP package most widely diffused on the market when the research was initiated.

The choice of SAP R/3 was motivated by three main reasons. First, the fact that SAP is the market leader in the sector guaranteed the existence of a large population of potential candidates for data collection. Second, most studies currently available on ES focus on SAP systems (Upton and McAfee 1998; Mandal et al., 2003; Abdinnour-Helm, 2003). Thus, restricting our research to a similar sample would facilitate the comparison of our findings with those already available in the literature. Finally, and perhaps most important, we had the possibility to directly benefit from SAP AG assistance to collect reliable data, which was one of the primary concerns of our study.

Information for this preliminary analysis was collected by means of face-to-face interviews with managers who were either responsible for project management or directly affected by the adoption of the new technology. The interviews were conducted personally by the main author of this work and took place between November 2000 and March 2001. They focused on the following aspects:

- an outline of the operational and organizational environment of the adopter
- an analysis of the main reasons for adopting the ERP
- a description of the main characteristics of the project
- an evaluation of the perceived success or failure of the project as well as an estimate of the long term impact exerted by the system on the organization.

The companies included in the sample had to respond to the following criteria:

- They should have completed the implementation of SAP R/3 between 1996 and 2000;
- they had to operate in different industry sectors;

- they had to be fully available to disclose information to the interviewer;

Five different companies have been included in this sample, namely[10]:

- Atom Energysystems
- International Petroleum
- Cosmetics International
- Bank United
- CD Coating Inc

2.2 Atom Energysystems

2.2.1 Company background

Atom Energysystems GmbH is the largest business unit of Atom Transmission and Distribution, the branch of an engineering company with worldwide activities. Once part of a different firm - ABC GmbH – the unit became part of the Atom corporation in the late 90's. Its main activities involve the design and the manufacturing of technical components for the transmission and distribution of electricity. The division is further subdivided across several smaller businesses, which include high voltage (HV), Protection and Control (PC) High Voltage systems (HVS), Decentralized Power Supply (DPS) and Transmission Line systems (TLS). Approximately 65% of the sales occur in the domestic market, with an annual turnover of € 610 M in 1999.

The organization is configured according to a peculiar mixed structure, which created numerous challenges during the implementation of their ERP system. From a logical viewpoint, the organization is subdivided into three levels: a *corporate* level, a *sector* level and a *business* level. Each sector includes several businesses, whereas each business contains all the units that operate in the same product market. Hence, the same business may have facilities in different countries, although not all the businesses are necessarily equally represented in all the countries where the corporation is established. However, from a legal perspective the structure is radically

[10] To protect proprietary information the name of each organization has been disguised

different. Different units located in the same country often belong to the same *legal entity*, even though they are part of different businesses (Figure 1).

Figure 1 ABOUT HERE

As a result, a business unit may exhibit some commonalities with other units that are located in a different country and that do not belong to the same legal entity. However, it may also display different types of similarities with some other units that are located in the same country (i.e. within the same legal entity) and that are part of a different business.

2.2.2 The process of ERP adoption and implementation

2.2.2.1 The pre-ERP situation: fragmentation of information

Atom Energysystems first considered the adoption of an integrated information platform in the early 80's (when it was still part of AGE GmbH), as a result of the need to harmonize the myriad of different legacy systems that characterized its IT infrastructure at that time. The adoption was initially triggered by AGE's decision to sell all the assets not directly related to its core business to an external company and to lease them back when necessary. The impressive amount of documentation and the many transactions required for the execution of this plan clearly pointed out the need for a drastic simplification of the company's data management systems and suggested the use of a common template for financial reporting. As a result, the integration effort was initially restricted to the finance and accounting department and it led to the adoption of the dedicated module of SAP R/2 in this department.

2.2.2.2 From diversified legacy systems to SAP R/2

Given the significant differences that existed between the business processes of Atom Energysystems at that time and those supported by R/2 in its standard version, the management was faced to the dilemma of how to render the new system functional to the business it was meant to support.

Following the rationale that an IT infrastructure should be adapted to the needs of an organization, an implementation strategy based on a full customization of the software was ultimately privileged. That is, it was preferred to preserve the peculiarities of the company's business architecture and to radically modify the structure of the IT system – even if that implied re-coding a significant number of routines. This particular strategy proved to be difficult to implement, quite costly and, above all, it created maintenance problem when new releases of the software were introduced on the market by SAP.

Furthermore, in spite of this first integration effort, the homogenization was limited to the finance and accounting department. The rest of the company's IS remained extremely fragmented and mainly based upon a multitude of ad-hoc systems developed autonomously by each department for its own special purposes. No automatic connections were established between R/2 and the other legacy systems. Furthermore, data had often to be entered manually, and in batches, for all the applications where they were required.

Apart from the lengthy process of information update, from the unduly data duplications and the large number of inconsistencies caused by the existence of multiple data entry points, this fragmentation of legacy systems was a source of major indirect costs. These costs were further accentuated by structure of the company (extremely decentralized) and were mainly connected to the following problems:

- The daily maintenance of the systems was extremely complex and required the existence of a huge and costly IT unit inside the company;
- Any modification or update of each software implied major changes and it was extremely expensive (often the software and those directly connected to it had to be completely re-designed)
- The fragmentation of the software also caused the fragmentation of the hardware behind it and further increased the difficulties related to maintenance;
- Information was not available in a timely fashion and reports were often delivered in batches, typically at the end of the month. This was particularly inappropriate for those functions that require a continuous – rather than periodical - supervision (e.g. project management).

2.2.2.3 The transition to SAP R3

In order to cope with these inefficiencies, Atom Energysystems decided to extend the adoption of an integrated information system to the entire organization and to migrate to SAP R/3. The decision was definitely approved *at the corporate level* in 1992. The first modules were operational in 1995 in a few pilot units, whereas the migration was finally completed only in 1997. The implementation process required significant efforts and it focused on three major aspects, namely:

- Customization of the software
- Standardization across departments
- Development of in-house ERP capabilities

2.2.2.4 Customization of the software

The strategy adopted for the rollout of R/3 was radically different than the one followed during the implementation of R/2. Mindful of the difficulties encountered during the previous experience with the customization process, the management preferred to preserve as much as possible the basic structure of R/3. Thus, whenever major inconsistencies occurred between the software and the structure of their business processes, the implementation team preferred to adapt the company's internal processes to the standard procedures contained in the software library, rather than to modify the architecture of the software.

2.2.2.5 Standardization across departments

A second key element of the implementation strategy was the attempt to standardize to a largest extent the system across different units, regardless of their specificity in terms of products, processes and organizational structure. In order to guarantee maximal harmonization it was thus decided to adopt a *common software platform* (i.e. the same basic processes) throughout all the company's units and to limit customization to those "front office" elements that would only affect the interface with the end users.

2.2.2.6 Development of ERP capabilities

A third and final key element of the implementation strategy was to favor the development of *internal* ERP capabilities, with the obvious long-term goal to foster a process of continuous process improvement, even after that the implementation was completed. This objective was achieved by setting up special working groups during the implementation phase, which always included *both* external consultants and internal "key users". The presence of the external consultant guaranteed the technical expertise necessary for the configuration of the software, whereas the internal key users had a twofold role. First, they had to assure that the company special requirements were correctly taken into account during the implementation. Second, and more important, they were responsible for guaranteeing the transfer of knowledge from the consultant to the organization. Each "key user" became an ERP champion and favored further knowledge transfer (internally to the company) during the actual use of the system for its daily operations.

2.2.3 Major benefits and implications

The adoption of SAP R/3 brought some of the expected benefits, but it also induced important modifications in the firm's business model. First and foremost, Atom Energysystems reported major improvements associated with the homogenization of information and to its timely availability. Homogenizing the information reduced significantly the number of data entry points, with a consequent decrease of potential inconsistencies and errors. In turn, this permitted a better utilization of resources, due to the reduction of the number of controls previously required to identify and eliminate data inconsistencies.

The second major advantage was the timely availability of information throughout the whole company. This property was particularly useful for a better risk management, especially for those activities that require a careful control of the processes and a prompt reaction to unexpected events. In the case of project management, for instance, the timely availability of information enables managers to follow the project status in real time, and, thus, to promptly take appropriate correcting actions when necessary. This improved capability has allowed Atom Energysystems to increase the number of projects finished on time and to reduce budget overruns. The timeliness of information has also positive impacts on the activities more directly related to manufacturing, where being able to control process in real time has increased the percentage of on time-deliveries and it has reduced both the inventory level and the manufacturing cycle time.

The replacement of the multitude of old legacy systems had also major HR implications, as it required a general reallocation of tasks and activities across functions (some employees experienced changes in their jobs after adoption of the new system).

The finance and accounting department were the functions that most benefited from the homogenization of information. However, the migration to the SAP R/3 did not introduce significant changes in these areas, where the only real difference was represented by the use of new software.

Conversely, major changes occurred for the jobs more closely connected with manufacturing and engineering. In the ERP environment the employees of these departments were asked to perform a larger amount of administrative work, and in a much more structured and repetitive fashion than before the ERP adoption. This reallocation of tasks required a great effort of change management to convince end users, especially those who were more significantly affected by the R/3 logic - of the potential benefits of the new system.

2.2.4 The next step: from a local implementation to a global roll-out

2.2.4.1 A global roll-out

After the successful experience at Energysystems division, the Atom corporation is now considering the rollout of R/3 in other sectors, even outside Germany. By virtue of its successful experience with the first implementation and of the competences already created in house, Energysystems GmbH is expected to guide the roll-out process.

This extension program poses interesting challenges to the whole organization. Some of them derive from the characteristic of the software *per se* and are also typical of many other ERP projects in different companies. However, some other challenges stem from the peculiar legal and organizational structure of Atom and may be relevant for other multinational corporations that have a similar organizational architecture.

2.2.4.2 The driving forces: global integration and local responsiveness

As any other multinational organization that operates in a multitude of different countries and markets, Atom is subject to the effect of two antithetical forces: the forces for *global integration* and the forces for *local responsiveness* (Ghoshal & Nohria, 1990).

The first set of forces advocates the largest possible level of standardization of products, processes and organizational routines - both across units and countries – in order to achieve significant cost savings and to exploit the benefits associated to the development of economies of scale. Conversely, the forces for local responsiveness suggest that each business unit within the multinational enterprise should follow a strategy of careful customization (i.e. the opposite to standardization) in order to optimally respond to the unique features of the markets in which it competes.

Needless to say, the effect of these two forces has also major implications for the ERP configuration strategy (Figure 2). In the ERP world, the forces for global integration strongly advocate for the standardization of ERP modules across different business units (i.e. the adoption of the same R/3 "best practices"), regardless of the business or the legal entity to which the unit belongs. Apart form the cost savings related to this strategy, a careful homogenization of the modules eases the roll out (i.e. the progressive implementation from one unit to another) and it also facilitates the daily use and maintenance of the software.

On the other hand, the forces for local responsiveness suggest that each unit should carefully customize the software to render it functional to the unique features of its main activities, regardless of the fact that this strategy may require significant changes in the software when this is rolled out from one location to the next.

Figure 2 ABOUT HERE

Clearly, a fundamental trade off exists between these two approaches. A complete standardization allows the enterprise to ease the implementation and to substantially reduce the consulting costs associated to the software customization at each location where it is implemented. However, when large differences occur across different businesses, the standardization strategy may not allow the ERP system to be best suited for the requirements of each specific business processes it is expected to support.

Conversely, a customization strategy is certainly more costly and more difficult to implement. However it allows the enterprise system to be perfectly functional to the needs of the business units and, thus, it helps the latter generate higher profits.

Furthermore, the peculiar structure of Atom adds an element of additional complexity into the picture, as the forces for global integration may exert their action in two different directions.

On the one hand, the corporation experiences the need for standardization of administrative procedures across business units that belong to the *same legal entity* and that are located in the same country, even though they are part of different businesses.

On the other hand, there is an equally important necessity of process standardization across units that belong to the *same business*, although these units may be part of different legal entities and physically located in different countries.

For instance, a manufacturing facility "XYZ" located in Germany, which produces parts for the high voltage business, may want to harmonize its enterprise system with other facilities of the same legal entity also located in Germany – even if these are part of a different business and manufacture completely different products. However, the unit also may also prefer to harmonize its processes with similar facilities that manufacture the same product, although they are located in different countries.

2.2.4.3 The Atom solution: differentiated standardization

Faced to the trade off between standardizing the enterprise system across businesses or legal entities, Alstom is developing a mixed strategy, which could be defined as a strategy of *differentiated standardization*. This consists of distinguishing among different modules and homogenizing some of them across businesses and some other across legal entities, depending on where the largest advantages are expected to be.

The harmonization across facilities that belong to the same legal entity (say the same country) is particularly advantageous for all the modules that control administrative and accounting procedures, as the latter do not depend on the particular business but, rather, on the specific legislation of the country where the firm operates. Conversely, the standardization across businesses brings the largest benefits for those modules that are related to the manufacturing or the design process *per se*. In fact, these processes are – so to speak – "product specific" and are not influenced by the particular legislation of the host country (Figure 3).

Hence, the high voltage facility "XYZ" located in Germany is likely to exhibit commonalities with other units located in the same country in the human resource management and accounting areas. Wages, taxes, administrative procedures and legal obligations are regulated by national standards and are typically independent of the particular business where the firm operates. Furthermore, the financial reports of the facility have to be merged with that of other domestic units. Obviously, using the same template simplifies enormously the task and reduces the administrative burden associated with this operation. As a result, the unit will certainly benefit from a complete alignment of its HR and financial accounting modules with those of other units located in the same country.

Conversely, if one considers processes that are idiosyncratic to the type of product sold (e.g. production planning, NPD or project management), it is evident that the focal facility is likely to display commonalities with other units that manufacture and distribute similar products, even if these are located in different countries. Accordingly, in these instances it is most beneficial to standardize the modules for production planning and project systems across similar businesses rather than across the same legal entity.

Figure 3 ABOUT HERE

2.2.5 Open questions and implementation challenges

Atom is concerned about two major questions related to its ERP roll-out strategy, which are symptomatic of some typical challenges faced by most business organizations that adopt an integrated IT systems.

First and foremost, the management is particularly concerned about the minimum size of a business unit that justifies the adoption of an ERP system. The issue is of particular importance for Atom, as the company is considering an extensive roll out program that will affect a large number of its subsidiaries. This question reflects a basic trade off between the benefits of process standardization and the cost of an ERP implementation. Even when in the simplest cases, adopting an ERP is long, complex and costly. Furthermore, the costs of implementation do not necessarily decrease linearly with the firm size, because of the occurrence of several types of sunk costs. On the other hand the expected benefits often do increase proportionally to the firm size, as they are related to the number of operations that the system is expected to streamline. However, even if it is most likely that small firms should consider an ERP adoption with extreme care, the optimal cut-off size remains unclear, because it also a function of the previous experience of the firm with the system and on the particular implementation strategy adopted.

A second open question is the extent to which the roll-out should concern Atom's first-tier suppliers and its business partners. These companies – typically owned by Atom and located in different countries – are small firms with extremely diversified products and processes (often the same company may supply raw materials or semi-finished products to many different Atom units, in completely different businesses and different sectors). As a consequence, a software standardization strategy may result particularly difficult, because each client company would push the supplier to configure the software according to its own requirements. Furthermore the relatively small size of these firms does not even permit the adoption of the differentiated standardization strategy followed by Atom energysystems. As a consequence, it is still unclear whether for these companies the adoption of enterprise systems will be beneficial – or even feasible.

2.3 International Petroleum

2.3.1 Company background

International Petroleum is a fairly large and partially state-owned company with activities in the extraction refining, distribution and sale of oil products. The organization is composed of several independent business units, which are responsible for the following activities: oil drilling, refining, distribution and sales. Although its headquarters are located in Western Europe and the largest proportion of its sales occur in its home country – the company has several refineries overseas.

International Petroleum is a fairly complex organization with several thousands employees, evenly spread across its different facilities. Its organizational architecture is still configured as an extremely structured bureaucracy - a legacy of its status of former state-owned monopoly – which comprises a large number of layers, often subdivided and managed by function, irrespectively of possible commonalities. By admission of many of the employees contacted, information flows quite slowly across these layers, and the decision making process is extremely articulated and fairly inefficient. These organizational characteristics had a profound impact on the ability of the firm to fully extract benefits from its ERP project.

2.3.2 The ERP project

Not surprisingly, the pre-ERP IT infrastructure of International Petroleum was characterized by a myriad of different legacy systems, which had been often developed autonomously by their different business units to respond to the idiosyncratic needs of the markets in which they operated and of the activities they performed. The migration to an ERP system was decided at the corporate level to streamline and standardize accounting processes and financial transactions, in line with a general trend observed in the oil industry in the mid-late 90's, when the adoption of an integrated information system was almost mandatory to remain competitive.

Given the number of sites involved and based on the belief that these sites shared a large number of process commonalities, the company decided to centralize the implementation and to establish an internal SAP competence center specifically dedicated to this project. The center, directed by an IT manager, coordinated the rollout of the system in all the different sites interested by the migration and continued to monitor the upgrades and the improvements that were introduced after the first wave of installations was completed.

The ERP project had a strong IT connotation and lasted about two years from the signature to the contract with SAP to the date when the first systems implemented became fully operational (1999). A major system update was necessary at the end of 2001 to manage the transition to the Euro – which occurred without major problems in January 2002.

2.3.3 Major benefits, caveats and open challenges

From a pure information management perspective the centralization and the rationalization of the different data management systems generated unquestionable benefits. However, the company also experienced a few unexpected difficulties, particularly in the period that immediately followed the migration to the new software.

First and foremost, International Petroleum noticed that it was virtually impossible to fully adapt the new ERP-supported templates to their original business processes. As a consequence, a number of particularly convenient organizational practices that had been specifically developed to facilitate the execution of daily operations had to be abandoned to accommodate the requirement of the new software.

Second, the company experienced difficulties in extending the functionalities of the software and in integrating it with the few legacy systems that were still in use after the migration occurred. Indeed, for purposes of convenience International Petroleum decided not to replace a few customized pieces of software that performed special functions. During the first implementation these legacy systems had been successfully connected to the new software. However, when upgrades (either for the legacy systems or for the ERP) became necessary it appeared clear that maintaining such a seamless level of integration would be extremely complex and difficult.

Third, International Petroleum observed an exacerbation of the endemic rigidity of its organization, which somewhat hampered its capacity to compete in rapidly changing markets. The phenomenon occurred as a result of the interaction between the characteristics of the new software and the organizational environment in which the system was called to operate. In an ERP-based environment each end-user becomes operational only after receiving an authorization and a password, which grant access to different levels of information in the system and permits the execution of a given set of activities (not alike for all employees). However, in the peculiar organizational environment of International Petroleum (a rigid bureaucracy that required decisions to be approved by different managers in different departments) the process of obtaining a new authorization was particularly long and painful and prevented some departments from redeploying their workforce according to the circumstances. The problem became evident when the firm undertook a major organizational restructuring, as a result of which a large part of its workforce was reallocated and new employees were hired. Due to the complex procedure necessary to generate an authorization in the new environment –newly hired employees or staff members who were assigned to new responsibilities could become operational only after a long amount of time. Exasperated by the situation – a few managers decided to overcome this limitation by sharing their own ID and password with their subordinates, with the result that a large number of end-users had access to information they were originally not supposed to.

Finally, and contrary to the prevailing wisdom, the company experienced an increase of its software maintenance and upgrading costs. This unexpected increase was mainly due to the fact that – in the new highly integrated environment – the minor changes frequently made after the live date generated a cascade process that necessitated the modifications of larger sections of the system.

2.4 Cosmetics International

2.4.1 Company background

Cosmetics Intl. co is a large multinational corporation that manufactures and sells cosmetic products. The company is composed of more than 40 independent subsidiaries located in various countries in Europe, America and Asia. The different subsidiaries are broadly subdivided into two main categories:

- Companies that manufacture or distribute large volumes of commodity-type of products for mass markets;
- Companies that manufacture or distribute small volumes of expensive luxury products for a more limited population of selected customers;

Despite these differences, the subsidiaries exhibit a certain number of commonalities from a production process standpoint, as the particular nature of their products require limited customization and relatively little adaptation to the needs of the local markets where the firms operate. Conversely, the degree of heterogeneity is quite significant for the administrative processes, which that are sensitive to the differences in regulations and tax structure across the various countries in which the companies are established.

2.4.2 The ERP project

Motivated by the need to homogenize its back-office operations, to rationalize its administrative processes and to control the cost of maintaining its IT infrastructure the company considered migrating to an integrated system in 1995 and to progressively roll-out the software to all its different subsidiaries. The first pilot systems became operational in 1997. At the end of 2002 39 companies had completed or were about to complete the migration, with the large majority of sites going "live" between 1998 and 1999. Improvements and updates are still ongoing for most of the locations interested by the project.

Well aware of the impact of this migration and of the potential dangers of a superficial implementation Cosmetics Intl. decided to undertake a major effort and established an internal SAP competence center. The role of this center was to develop a set of common process platforms or "core systems", which should replace the processes previously in use at each location. Given the different needs arising in the organization, two different models were created for the core systems:

- A model "core systems finance": mainly aimed at homogenizing accounting and financial processes across different subsidiaries and between subsidiaries and the headquarters;
- A model "core systems integrated": aimed at streamlining physical processes and at integrating them across each other within the same facility.

Each project was based on one of the two models above, depending on the type or operational priorities of the site interested by the implementation. Hence, 18 sites followed the "finance" template, 19 the "integrated" one, whereas the software of one site that had idiosyncratic processes was developed outside the core system framework.

The projects based on the first archetype were somewhat more IT-oriented and required a higher number of consulting hours than implementations based on the integrated core systems, which demanded a more important involvement of internal users. These projects had also a stronger IT outlook, whereas in integrated implementations it was dedicated proportionally more attention to the phase of gap analysis that precedes the software configuration per se. The system rollout inside each facility was also slightly different in the two cases: projects based on the "integrated" template had a progressive rollout, whereas the other model privileged a big-bang approach.

Given the large number of different organizational processes and legacy systems that characterized the pre-ERP era, the competence center responsible for the development of the process templates was confronted to the decision of how much standardization to enforce across the various business units by means of the common templates.

Despite the pressure exerted by many subsidiaries that pushed to maintain their previous operational procedures and to customize their ERP implementation, the company decided to enforce standardization to the largest possible extent: the customized processes that existed in the pre-ERP era were preserved in the new environment only if they were already shared by at least two companies in the organization.

2.4.3 Major benefits, caveats and open challenges

The scale of the project and the large number of sites interested by the adoption does not permit to draw general conclusions. However, several interesting observations suggest themselves.

The first observation is that the subsidiaries that followed the "integrated" model for the development of the core systems generally exhibit larger operational benefits than the companies that adopted the "finance" template. This difference is possibly due to the fact that projects based on the former model required the utilization of a proportionally larger amount of time and resources to streamline processes. In turn these efforts were likely to foster a continuous improvement attitude, which continued to extort its beneficial effects even after the project completion.

In the organizations where the implementation was based on the "finance" core systems the efforts dedicated to the adoption of common accounting standards and reporting procedures determined a sensible improvement of the performance indicators more closely associated to these activities. However, these improvements often took place at the expenses of other operational areas in which it was observed a deterioration of performance.

The second interesting remark is that the fact that the strong commitment to the project and the allocation of a large amount of resources dedicated to its development had a secondary and undesired effect. On the one hand this commitment certainly guaranteed the success of many rollouts and the achievement of operational improvements in many business functions. On the other hand, it also caused difficulties in the management of routine activities that were not directly linked to the ERP implementation. Indeed, some subsidiaries reported that the allocation of most of their best employees to the ERP implementation project caused a shortage of critical resources and ultimately hit the daily operations of the firm.

2.5 Bank United

Bank United is an international company that operates in the banking sector. Its headquarters and the largest majority of its branches are located in Switzerland. Its experience with the rollout of SAP R/3 is interesting to highlight the importance of a few critical factors that may affect the ultimate success of an ERP implementation from a project management perspective.

At the time of the ERP implementation the structure of the organization was the result of a recently occurred merger between two separate business entities: Bank A and Bank B. Bank A – which had already adopted SAP R/2 before the merger – possessed an extended experience with integrated information systems. Conversely, Bank B was relatively inexperienced in that respect: its IT infrastructure before the merger was composed of a collection of independent legacy systems, often not connected among each other.

The company decided to migrate to an enterprise system to address two basic needs:

- the need to further integrate the two organizations by means of a common process platform;
- the need to update and improve the performance of the accounting department in both organization;

Despite the fact that the need to amalgamate the two business units would have suggested the development of major re-engineering efforts, the implementation was somewhat managed like a small-scale project and mainly outsourced to a large consulting firm with extensive experience in accounting and financial services.

The project was developed and managed locally and it had a limited penetration into the company's core activities. The implementation involved three different groups:

- facility managers
- accountants
- controllers (who were the ultimate clients and the ones most extensively affected by the new system).

Worried about a possible escalation of the project cost, pressed by the need to create common standards across the two business organizations, and concerned by the different expectations of the three groups involved, the project leaders adopted a rigid deployment model that left very little room to incorporate feedback from end-users and to implement second-order adjustments along the road. Furthermore, the rollout occurred in an accelerated fashion and it was mainly driven by the external consultants, who developed all the necessary training material and scheduled the agenda for the implementation.

In spite of this tight implementation model and of the careful control exerted by the team the project was a failure and it was eventually dismissed because the controllers ultimately refused to use the new software.

Most of the managers interviewed about the failure pointed out that the little (virtually nil) involvement of the controllers in the configuration of the system and in the development of the training material was the most likely cause of the enormous resistance to the change observed.

2.6 CD Coating Inc.

CD Coating Inc. is a multinational corporation that manufactures coating machines for the production of CDs. Although its headquarters are located in Liechtenstein it has several manufacturing facilities, both in central Europe US and Japan.

The nature of the product and the internal architecture of the organization pose several logistics and production planning challenges, which have influenced the decision to adopt an ERP system. First and foremost, the characteristics of the product manufactured constraints CD Coating to maintain a lean production system.

Because of the continuous technological innovations that occur in this industry and of the steep learning curve in the manufacturing process, inventory becomes rapidly obsolete and must be kept to a bare minimum. Hence, in such a context - where demand fluctuations cannot be addressed by holding excess inventory - responsiveness becomes a key operational priority.

Second, although operations are global and although the product does not need to be adapted to market-specific requirements – the firm is organized locally. Each location is managed as a separate business unit and – also – as a separate legal entity. The coexistence of these local and global needs creates conflicts and it was indeed one of the reasons that motivated the adoption of an enterprise system. As a matter of fact, CD Coating Inc decided to migrate to an ERP system to ameliorate the management of information but also to increase the responsiveness of its operations and to benefit from the obvious process communalities across its different facilities.

Mindful of the risk of underestimating the complexity of such a project, CD Coating considered the ERP implementation as a top priority initiative. The team had the strongest sponsorship from the firm's executives and it was provided with full support throughout the whole duration of the project.

To maximize the effect of scale economies the company chose a global implementation and it decided to deploy the systems simultaneously in the different locations. However, the existence of four different legal entities forced CD Coating to decentralize the implementation and to delegate the design of the new business processes to the individual business units. As a result of this choice and in spite of the resource allocated and of the top management commitment, the coexistence of four different legal entities with conflicting priorities created numerous problems and significantly delayed the project.

2.7 From anecdotal evidence to an integrated framework

The examples discussed above illustrate some of the typical issues that arise before, during and after the implementation of an enterprise system. They also highlight a few operational and organizational consequences that this technology produces once it is adopted and in use.

First and foremost the examples confirm that the migration to an integrated information system cannot be regarded as a standard IT project, for at least three reasons:

- The cost, the resources necessary for its development and the duration of a typical ERP implementation are by far larger than those of an "average" IT project;
- The impact exerted by an ERP system is broader and more profound than that of most IT products. It overcomes the boundaries of an IT department and touches upon the firm's organizational, operational and financial sphere;
- The configuration of the software often requires the adopter to engage into a major business process re-engineering initiative, which may significantly reshape its operating practices and – ultimately – its way of doing business.

The examples analyzed shed also some light on the different types of impact exerted by the technology in the long run, as well as on the critical elements that determine the success or the failure of implementation per se. A large majority of companies report that the migration to an integrated information system modifies the responsiveness of their organization, either positively or negatively, thereby suggesting that an ERP is not merely a transactional instrument. Two antithetical phenomena determine this impact. On the one hand the improved access to information enables a more timely control on operations and increases responsiveness. On the other hand, the structural rigidity of the system may prevent some organizations from promptly redeploying resources, thereby reducing their agility.

It is also quite evident that the enterprise systems must be also analyzed through an organizational lens, as they both affect and are affected by the environment in which they are implemented. On the one hand migrating to an ERP-based IT infrastructure requires the adoption of a set of new organizational practices that may clash against the ones already in use. On the other hand, as illustrated by the example of International Petroleum, the organizational characteristics of the adopter may in turn affect the performance of the new technology and create unexpected difficulties.

The five examples also point out to some the most typical decisions that an organization faces during the configuration of the system, which may ultimately influence the effectiveness of the system and attenuate some of the effects cited above. These include:

- The degree of process standardization that it is convenient to achieve across the different sites interested by the implementation;
- The degree of software customization (i.e. the extent to which the adopter modifies the process templates to adapt them to its pre-ERP practices);
- The extent to which external consultants participate in the project and the role that they play;
- The extent to which end-users are involved in the implementation;
- The magnitude of the business process reengineering efforts undertaken before the configuration;
- The pace of the deployment, which may span from a progressive roll-out to a big-bang implementation where multiple sites become operational simultaneously.

The impact of these factors is complex and often not univocal, hence difficult to interpret. Nonetheless, these exploratory findings are a useful point of departure to start shedding some preliminary light on the research questions discussed in chapter1.

1. What are the mechanisms through which IT adoption affects operational effectiveness? As expected, the impact of an ERP implementation spans across several operational areas and cannot be restricted to the mere IT domain. Certainly, most companies mentioned their improved capacity to manage information and data as a key benefit. However, the example of Integrated Petroleum (that reported a reduction of organizational agility after the adoption) and the case of Atom Energysystems (that was forced to redesigned its business architecture to spouse the ERP structure) also suggest that an enterprise system implementation may have far-reaching consequences, which involve other operational and strategic areas.
2. Is the impact of IT adoption contingent to the specific organizational and industry environment in which the adopter operates? Again, the examples analyzed seem to confirm that the pre-implementation environment (Abdinnour-Helm et al., 2003) - affects both the success of an implementation and the

ultimate ability of the adopter to extract operational benefits from the new technology. For instance, the case of Integrated Petroleum suggests that organizations configured as structured bureaucracies are more exposed to the risk of diminishing their organizational agility in an ERP environment.

3. What are the phenomena and the cognitive mechanisms that subsume the generation of IT capabilities? Our preliminary findings confirm that an ERP adopter must undertake important cognitive efforts, to overcome at least two types of knowledge barriers: configurational (i.e. IT-specific) barriers, which originate from the need to parameterize the software, and assimilation barriers, which conversely arise when end users need to assimilate the new ERP-based business processes (Dobery et al. 2002). The examples reported also confirm the critical role played by some of the success factors that are most commonly cited in academic studies and industry surveys. For instance the difficulties encountered by Bank United to manage the change process are symptomatic of the importance of involving end-users in the development process.

To further examine the questions above, in the following chapters we use these preliminary findings to propose a theoretical framework that – by combing organizational theory and the resource based view of the firm – attempts to explain how and under what conditions the adoption of an ERP system may generate operational improvements and – possibly – sustained competitive advantage.

Chapter 3

Towards a theory of ERP-driven profitability

3.1 Introduction: the ERP phenomenon in the management literature

Initially regarded as a phenomenon of great relevance for the business world but of little theoretical interest it is not until recently that ERP systems have received attention from the academic community in a systematic fashion. However, perhaps as a consequence of the initial bias and of the fact that "getting he system to run" is often the first urgent priority of most ERP adopters, research in this area still abound of "exploratory surveys, targeting common and ubiquitous issues like cost, time and success" whereas "studies on usage and extendibility for operational and strategic benefits have been much less common, regardless of the fact that such issues most likely represent the motivating long-term rational behind adoption in the first place" (Jacobs et al., 2003, p. 234).

Indeed, most of the early research on the topic was somewhat restricted to technical problems and relegated to programmers and to specialists of the human-computer interaction. Faced to contradictory evidence, management scholars now univocally recognize that the impact exerted by these technologies is so profound and complex that it can be assessed only through a multidisciplinary research lens, which encompass strategic and organizational aspects.

It is convenient to subdivide research on ERP systems into concept-oriented and systems-oriented studies (Jacobs et al., 2003). Concept-research "would tend to focus more on the potential impact of ERP on the various business functions [supported by the system]. In contrast systems- research would tend to focus on the intricacies of package and process design to meet such conceptual objectives" (Jacobs et al., 2003, p. 236). From a methodological perspective the above distinction implies that systems-oriented studies tend to use project success as dependent variable, whereas concept-oriented works focus on performance indicators that assess the operational effectiveness of the business units involved in ERP projects along a number of dimensions.

Systems research builds upon a long tradition of IT research, which attempts to identify the critical factors that influence the success of a project. As mentioned in chapter 1 these works – which range from anecdotally motivated theoretical frameworks (Cliffe 1999; Prasad et al 1999; Markus et al. 2000) to empirically supported investigations (Holland and Light, 1999; Mabert et al. 2000, 2003;) - mainly take a project management perspective and investigate the role of the various key factors that are often cited by ERP practitioners as the most critical issues during an enterprise project. These factors are consistent with the preliminary observations that we have reported in chapter 2 and include for instance, a clear understanding of the objectives and of the strategic goals of the project, the commitment from the top management, the use of highly qualified implementation teams, the role of change management, the importance of data accuracy, the role of education and training and the importance of adopting focused performance measures (Davis et al., 1998; Krupp, 1998; Laughlin, 1999; Maxwell, 1999; Minhahan, 1998; Sherrard, 1998). However, in spite of their richness, these studies are mostly exploratory in nature and they tend to provide little theoretical explanations for the phenomena analyzed.

In contrast, other studies that can be ascribed to the concept-oriented category tend to focus the impact of ERP systems on specific operational areas such as supply chain management (Akkermans et al., 2003) or knowledge and information management (Van den Hoven, 2001). Rather than focusing on the implementation success these researches discuss methodologies or operational framework that may facilitate the use of ERP systems to ameliorate the performance of certain specific business functions such as inventory management (Mundal et al., 2002), or resource planning (Frederix, 2001). Along these lines Upton and McAfee (2000) apply the widely accepted notion of continuous improvement in manufacturing management to examine whether and under what conditions the adoption of an ERP system may initiate a virtuous process of this nature.

For sake of completeness it is also appropriate to mention a separate stream of research that – as a natural continuation of the "IT productivity paradox" paradigm – uses economic data to examine the existence of a correlation between the intensity of ERP investments and productivity (Hitt et al. 2002). Despite their analytical rigor, these investigations use data that typically do not include organizational or project-level variables, thereby somehow overlooking the impact of the implementation strategy.

The few examples cited above are symptomatic of the generalized interest for ERP systems that characterize the academic community. However, they also suggest that research in this area has mainly occurred in a compartmentalized fashion and that there is an urgent need for more process oriented research that "bridges the gap between the systems and the concept considerations" (Jacobs et al., 2003, p.237). Efforts in this direction have been already undertaken by Sarkis and Sundarraj (2000), Bendoly and Jacobs (2002) or by Soh et al. (2000), which examined the occurrence of "fit" and misalignments between best practices and international cultural differences. Our work is the natural continuation of these endeavors.

3.2 A process-oriented model of ERP-driven profitability

Management scholars and industry practitioners increasingly recognize that ERP systems should not be merely regarded as tools with a fixed and measurable output, but rather as technological infrastructures designed to support the capability of all other tools and processes used by a firm (Bendoly, 2001). This consideration – together with the evidence collected from the cases summarized in chapter 2 suggest that a holistic approach is most appropriate to unveil the mechanisms through which the adoption of this technology affects the operational effectiveness and possibly the profitability of a business organization.

To this end, we develop the general framework of ERP-driven performance that is schematically drafted in Figure 4 and that will serve as a basis to develop the specific models tested in chapters 5 and 6. By drawing upon the resource based view of the firm and organizational learning theory this general framework explains through which mechanisms and under which conditions the adoption of an enterprise system may affect operational effectiveness and possibly – business performance.

The proposed scheme is based on the appreciation that enterprise systems have a much larger impact on organizations than other IT classes, because they affect simultaneously the three "cores" of a business (IS, administrative and technical) and because their implementation is accompanied by a business re-engineering efforts that interferes with the *knowledge development processes* through which the firm generates and maintain competitive advantage.

The central tenet of our argument is that the impact of an ERP on the performance of a business organization is primarily the result of phenomena that occur at the *operational* level and that also influence the productivity of the business units. However, we also recognize that these operational phenomena are *de facto* influenced by a number of "soft" organizational factors that are typical of the project implementation phase and that shape, so-to-speak, the "personality" of the system. Finally, we observe that the whole process is moderated by an important exogenous variable – the degree of turbulence of the firm operating market - which is not under the adopter's control and may amplify or attenuate the above effects.

Figure 4 ABOUT HERE

3.2.1 Drivers of performance improvements

Starting from the right hand side of Figure 4 we note that the adoption of an ERP is expected to increase the profitability of an organization primarily through the benefits that it generates at the operational level (e.g. a decrease of operating expenses, an increase of product quality, an improvement of customer service and supply chain responsiveness). However, we also observe that – while the achievement of operational improvements is recognized as a primary driver of profitability increases – it is not a sufficient requisite for securing sustained competitive advantage (Porter, 1996).

The resource-based view of the firm theorizes that organizations with valuable, rare, inimitable and non-substitutable resources can achieve sustained competitive advantage if they are capable to integrate and use these resources in a way that cannot be easily duplicated by direct competitors (Barney, 1991;Barney, 1986) (Nelson 1991; Conner and Prahalad 1996; Eisenhardt and Martin 2000). This advantage is also further augmented if the strategy implemented exhibits complementarities with the systems and the technologies that are expected to support it (Milgron and Roberts 1990; Collis and C.A. 1995; Porter 1996). Hence, an ERP implementation can guarantee the achievement of sustained competitive advantage if two additional conditions are realized, namely.

- the impossibility for the firm's competitors to imitate the new ERP-based business processes;
- the existence of complementarities between these new business processes and the overall strategy;

Both conditions are connected to the fact that the adoption of an enterprise system generally forces the firm to assimilate new business processes, which may be quite different from the ones that characterized the pre-ERP era (Robey et al., 2002). This has important implications for the firm's ability to generate and, especially, to maintain competitive advantage.

In chapter 5 we will demonstrate that - unless appropriately modified - the logic of an enterprise system intrinsically privileges process effectiveness with respect to process flexibility and generates higher operational benefits for firms that operate in stable markets. Hence, a technology with these characteristics is naturally more appropriate for firms that compete on cost, for which a small improvement of operational effectiveness may be sufficient to outperform direct competitors. Conversely, ERP adopters that base their core strategy on customization or differentiation are more likely to experience a misalignment between their strategic choices and the characteristics of the enabling technology that has been specifically adopted to support them.

Second, we also observe that the probability of achieving competitive advantage is moderated by the extent to which the firm follows a *customized implementation.* As a consequence of the inherent complexity of the system, many adopters are afraid of incurring in technical problems that may delay the project. Thus, although it is possible to customize the software by coding new procedures (Davenport 1998), many firms prefer to follow the standard configuration scheme suggested by the software vendor, which typically minimizes the amount of ad-hoc interventions on the software and the risk of incurring in technical failures.

However, this strategy has its intrinsic dangers too, as it may forces adopters to abandon some of the distinctive features of their business model and to choose its new processes among a limited number of built-in alternatives already stored in the software library. Since these alternatives typically differ from the firm original processes and may also be available to competitors that adopt the same technology, not only ERP adopters that opt for a standard configuration may expose themselves to the risk of destroying some of the inimitable features of their business model, but they may also increase the probability of being imitated by a competitor who adopts the same technology and a similar configuration scheme.

Although this is not particularly dangerous in environments where the competitive pressure comes from cost effectiveness, or for firms which original business model was not particularly effective and needed substantial revisions, it may well prove to be hazardous in two other situations. First, when the need to differentiate processes from those of its direct competitors is a key condition for the very survival of the organization. Second, and regardless of the type of strategic choices made, when the original business model to be replaced by the ERP-based one was already particularly successful and indeed constituted one of the firm's sources of competitive advantage.

3.2.2 Drivers of operational improvements and project success

As a second step, proceeding backwards along the diagram of Figure 4, we examine the mechanisms through which an ES helps adopters realize the planned operational improvements. The theory of dynamic capabilities suggests that, in order to increase operational effectiveness, a process-oriented technology should enhance the firm's ability to promptly reconfigure its organizational routines to address rapidly changing markets (Pisano 1994; Teece, Pisano et al. 1997). However, it is also widely acknowledged that this capacity does not arise spontaneously. Conversely, it is produced by deliberate knowledge investments undertaken by the firm (Zollo and Winter, 2002) and it is also reflected by two major properties of the firm's operational processes, namely: *effectiveness* and *flexibility*.

Our major claim is that the operational impact of an enterprise system is a consequence of the fact that the software interferes with the knowledge evolution cycle behind the genesis of these dynamic capabilities (Zollo and Winter, 2001), and that it does modify *both* the effectiveness and the flexibility of the firm's processes. We also suggest that this impact can be subdivided into two components, namely:

- a structural impact (technology-specific and independent of the firm's characteristics)
- an organizational impact (firm-specific and independent of the technology).

The first impact stems directly from the characteristics of the software and it can hardly be influenced by the adopter, whereas the second depends on firm-specific attributes and on how the firm manages the implementation process. As such, it is entirely under the adopter control and can be used by the far-looking managers to further increase the advantages of an ES.

3.2.2.1 Structural impact

The structural impact originates from the particular architecture of the software, which forces the adopter to reorganized its business processes according to a predetermined set of "reference models" (Keller and Teufel 1998). Not only does an ERP system replace existing legacy systems. It also replaces the processes supported by these systems with new standardize processes that cut across different functional applications. This replacement "requires firms to assimilate new business processes and new management structures" (Robey et al., 2002, p. 28), which may profoundly differ from the ones that characterized the pre-ERP era.

This need to map and optimize business processes and to adopt new reference models typically induces an ERP adopter to undertake important *knowledge articulation* and *codification* investments (Zollo and Winter, 2001). It also requires the adopter to overcome two types of knowledge barriers: configurational (i.e. IT-specific) barriers, which originate from the need to parameterize the software, and assimilation barriers, which conversely arise when end users need to assimilate the new ERP-based business processes (Dobery et al. 2002). In turn, these investments interfere with the process through which the firm generates dynamic capabilities and produce organizational routines that are structured and extremely efficient but also quite complex and long to modify.

As a consequence, whereas one of the primary goals of an ERP adoption should be the assurance of flexibility for corporate processes (Jacobs et al., 2002) – we suspect that this may not always be the case. Certainly, we recognize that an ERP adoption is always likely to increase the effectiveness of business processes because it helps organizations manage transactions efficiently. However we also note that - unless adequately controlled through appropriate actions undertaken during the implementation process – the system may also diminish organizational agility, as experienced – for instance - by Integrated Petroleum in the example reported in chapter 2.

3.2.2.2 Environmental contingencies

Even in the realm of ERP adoptions, management scholars increasingly challenge the global robustness of the so-called "best practices" and recognize the occurrence of contingency factors that moderate the outcome of an ERP adoption (Soh et al., 2000). In line with this perspective, we suggest that the impact of the structural effects discussed above is neither strictly positive nor strictly negative. Conversely we propose that it is contingent on the *degree of turbulence of the firm operating market* and, again, on the *degree of complementarity between the new business processes and the overall strategy* of the organization.

We will further develop this argument in chapter 5. Suffice it to say here that in stable markets where the competitive pressure comes mainly from cost effectiveness ERP adoption is always expected to generate higher operational benefits, because the need to increase process effectiveness usually offsets the risk of simultaneously decreasing flexibility. Conversely, in highly dynamic markets (Eisenhardt and Martin, 2000) where the competitive pressure comes from responsiveness and differentiation a reduction of process flexibility can be intrinsically more hazardous (even if accompanied by a simultaneous increase of effectiveness).

Furthermore, we observe that this potentially undesired effect could be attenuated by *appropriate actions undertaken during the implementation process*, which indeed determine the nature of the "organizational" impact of an ERP and that can be used by the far-looking manager to turn any ERP project into an impressive competitive weapon.

3.2.2.3 Organizational contingencies and implementation-specific impact

Contrary to the prevailing corporate wisdom that until a few years ago identified the implantation of an ERP as a mere technological challenge, both IT consultants and management scholars increasingly recognize that organizational aspects play a decisive role in most ERP projects. Factors such as the pre-implementation attitudes and the degree of organizational readiness (Abdinnour-Helm, 2003) may profoundly affect both the success of an implementation per se and the ability of adopters to extract long-term benefits from the new system.

In line with the argument developed in the previous paragraphs, we are particularly interested in the impact of organization-specific attributes on the cognitive process that subsume the generation of dynamic capabilities. To this end – and proceeding towards the left hand side of Figure 4, we observe that the ability to generate effective and flexible processes requires the development of appropriate competences inside the organization. These competences – which are identified as the true differentiating factor across IT adopters (Bharadwaj, 2000) - are typically created by carefully balancing the *technical and process knowledge* of IT consultant and the *operating expertise* of "business process owners" (Mandal et al., 2003). For instance, the experience of Bank United reported in chapter 3 confirms that poorly designed training programs (which are entirely managed by external consultant and imposed to end users) may produce the well-known "not-invented-here" syndrome and create important change management hurdles.

To further precise the role of organizational attributes on these knowledge-development activities we suggest that the ability to develop or share knowledge is influenced by two firm-specific variables:

- the *degree of coerciveness* of the firm bureaucracy
- the *degree of fairness* of the implementation process

First, we note that a coercive bureaucracy (Adler and Borys 1996; Adler, 1999) uses task formalization to impose conformity to existing procedures and to impede deviation from standardized practices. An organization that displays coercive characteristics is more likely to use an ERP as a control instrument thus further diminishing the flexibility of its processes. Conversely, a bureaucracy with an enabling attitude (i.e. non-coercive) is likely to use formalization instruments such as an ERP to encourage employees to search for new and more effective process structures and resource allocation schemes. Thus, *ceteris paribus*, an organization with this property is more likely to use an ERP to facilitate the exploration of new solution and to further augment the flexibility and the effectiveness of its processes.

Second, we observe that, "the existing organizational structure and processes found in most companies are not compatible with the structure, tools and types of information provided by ERP systems. Even the most flexible ERP system imposes its own logic on a company's strategy organization and culture" (Umble et al., 2003, p. 245). By contributing to the design of new procedures and to the formalization of workflows, the implementation of an enterprise system is 'de facto' a process of organizational design that requires the adoption of new management structures (Robey at al. 2002). Overcoming internal resistance to these changes may be indeed one of the most critical aspects of many ERP implementations.

Consistently with these observations, we suggest that implementation strategies that favor the establishment of enabling bureaucracies are expected to minimize the resistance to change and improve the operational impact of the system. We allso suggest that the *degree of fairness of the implementation* process (Kim and Mauborgne, 1996; Kim and Mauborgne, 1995)- together with its basic constituents *engagement*, *explanation* and *clarity of expectations* – is the dimension that is most functional to this purpose and the one that most increases the firm's ability to modify its organizational routines. By inducing voluntary cooperation (both among employees and between consultants and employees) a fair process facilitates knowledge sharing and development, reduces the users' resistance to change and it augments their ability to leverage the new processes and management structures introduced with the new technology. Conversely, we expect that "if people are not properly prepared for the imminent changes, then denial, resistance and chaos will be predictable consequences of the changes created by the implementation" (Umble et al., 2003, p. 245).

3.3 A comprehensive contingency framework

The above observations can be combined to derive a comprehensive contingency framework that suggests under what conditions an ERP adoption is likely to produce the largest advantages. Controlling for other exogenous variables, we expect enterprise systems to generate the highest operational benefits in organizations that:

- operate in complex but stable environments, where managing effectively a large number of transactions is a higher priority than the need to quickly find new business models;
- create internal knowledge by *carefully balancing* the use of external consultants to quickly configure the software and the development of internal competences that remain in the organization even after the project completion;
- have a culture that rely on task formalization, rules and procedures to enable and empower employees rather than to blindly impose compliance to norms;

- actively involve end-users in the roll-out of the project since its very beginning by giving them the possibility to participate into the design of the new organizational processes;
- undertake explicit communication efforts throughout the whole project development;

Furthermore, we expect these benefits to be further augmented and to generate appropriate financial returns (relative to the industry average) if:

- the firm competes in a market where cost effectiveness and supply chain responsiveness are higher priorities than product differentiation
- the adoption of the enterprise system generate business processes that are difficult to replicate for the direct competitors of the firm

At the opposite end, an ERP system is expected to produce the lowest operational benefits for organizations that compete in extremely dynamic markets, whose bureaucracies display few enabling characteristics and in which the system was substantially imposed to end users. In this case the disadvantages created by the decrease of process flexibility (which was not moderated during the implementation process) overcome the benefits associated with increased process effectiveness. The effect is even more severe if the firm's strategy privileges responsiveness and diversification rather than cost effectiveness and if the business model produced by the ERP adoption may be easily imitated by competitors.

In the remainder of this dissertation we use this general framework to address the three research questions that we have highlighted in chapter 1. More specifically in chapter 5 we focus specifically on the structural impact of an ERP adoption on the genesis of dynamic capabilities, whereas in chapter 6 we examine the role of the knowledge investments undertaken during the system implementation, and the importance of aligning the implementation strategy to the characteristics of the internal and external environment in which the adopter operates.

Chapter 4

Research design and data collection

4.1 Research design and sample selection

To address the research questions discussed in the previous chapters, we deemed appropriate to carry out a statistical analysis of a cross-sectional sample of companies that completed the implementation of an Enterprise System in the past decade. The type of questions that we sought to address and the nature of the variables included in the analysis – which concerned both "hard" operational and "soft" organizational aspects – suggested that the direct collection of primary data was the most effective research strategy.

Accordingly, we decided to gather primary data by contacting a representative sample of business organizations in Europe and overseas that had recently adopted an enterprise system.

To maximize the robustness of the study and to control for possible confounding effects we required that the firms included in the sample satisfy the following criteria:

- They had to use the same software from the same ES vendor;
- They should belong to different (yet comparable) industry sectors with different degrees of market dynamism;
- They should have completed the implementation at least one year before they reported the results of their experience (so as to be able to soundly assess the impact produced by the ERP system on their operations after the initial phase of chaos that typically follows the migration);
- They had to have experienced antithetical results (i.e. the sample should ideally contain both "champions" and also companies that faced problems either during or after the implementation).

Consistently with the case studies presented in chapter 2, we decided to focus exclusively on companies that adopted SAP R/3[11] and that went "live" between 1996 and 2000. Based on these considerations, we restricted our attention to companies in

[11] The decision to focus uniquely on R/3 (rather than on the newer mySAP.com) was mainly dictated by the need to obtain reliable data. Given its recent market introduction, for mySAP.com it would have been virtually impossible to identify a large sample of companies that had already completed the implementation and were able to provide a reliable evaluation of the system impact. However, this particular choice does not undermine the generalizability of our analysis, as we address process phenomena that are mostly independent of the particular technology adopted.

three main industrial sectors of the SAP internal taxonomy (process industry, discrete manufacturing and consumer products) that implemented R/3 between 1996 and 2000. Indeed, most of the companies actually included in the sample went live within an even narrower interval (between 1998 and 1999), which was an even stronger guarantee of the homogeneity across the software versions implemented.

For purposes of easier data collection we also decided to restrict the analysis to four representative European countries (France, Germany, Belgium and Italy) as well as to North America[12]. The selection of a final sample from the population of firms that satisfied the above criteria was achieved with the valuable assistance of three SAP regional subsidiaries and of two local SAP User Groups (country-based associations of SAP clients completely independent of the software vendor). In each region of interest we asked these organizations to select a sample of around 100 R/3 clients from their population of customers or members (for the SAP User Groups) that met the inclusion criteria and to indicate a contact person in each organization.

To limit selection biases, we particularly emphasized the fact that in order to obtain robust results the sample had to contain companies with antithetical implementation histories (i.e. both successes and failures). Both partners had a strong interest in obtaining unbiased results and agreed with this request. Our final sample contained 560 companies in the following countries: France, Germany, Italy, Belgium, US and Canada.

4.2 Questionnaire design and administration

After the selection of the final sample of potential respondents, the first step of our data collection strategy consisted in conducting a series of semi-structured interviews with executives from five European companies in different industrial sectors. The purpose of these interviews was twofold: i) to submit our conceptual framework to a first empirical validation in order to assess its face validity and ii) to define specific metrics for the measurement of the variables included in the specific models outlined in the following chapters.

Based on the feedback from these interviews, we developed a detailed questionnaire that covered four major themes: i) the operational and organizational

[12] The choice was based on two criteria: the fact that the author could master the language of the country chosen and the relevance of the particular market for SAP.

environment of the ES adopter; ii) the software implementation process; iii) the organizational and operational changes occurred in the organization after the implementation and, finally, iv) an evaluation of the changes observed in the firm key performance indicators after the system went live. To obtain comparable results across projects developed at different points in time we asked respondents to consider a time interval of one year after the live date when evaluating the changes produced by the software[13].

To maximize the precision of our measures and the intelligibility of the items we prepared three different versions of the questionnaire in three different languages (English, French and Italian) and we personally pre-tested each version with representative SAP clients in the target countries[14]. The revised version of the questionnaire was finally administered to the 560 companies in the sample via either e-mail or airmail.

Given the self-reported nature of the data collected we paid particular attention to give respondents strong incentives to provide accurate answers so as to limit biases. Towards this end we adopted the following strategy: i) we guaranteed that the information collected would remain completely confidential (especially vis à vis SAP AG); ii) we agreed to distribute to each respondent a personalized feedback document where each company's individual project was benchmarked against the overall sample of participants and iii) we agreed to share with respondents the final results of the study.

The questionnaire was administered to a general manager who supervised or sponsored the project or who was ultimately involved in performance evaluation. To guarantee that each completed questionnaire could be used in our analysis as a single and representative data point we asked respondents to complete the survey on behalf of the part of the organization that was under their direct responsibility and to report

[13] This interval was identified during our preliminary interviews as the best compromise between two antithetical needs: i) the need to observe long-term structural changes produced by the ERP (as opposed to short term perturbations due to post-implementation adjustments) and ii) the need to measure the changes before the memory of the phenomena of interest would fade away.

[14] We preferred to administer the English version of the questionnaire to the companies located in Germany, because we did not have a sufficiently deep knowledge of the language to translate it personally and because we wanted to avoid the use of an external translator not familiar with the ERP jargon. The choice was validated through a pretest.

this information. For small companies the unit of analysis typically coincided with the entire firm whereas for larger groups responses mainly referred to the strategic business unit under the direct responsibility of the respondent.

4.3 Representativeness of the sample

We received a total of 82 answers with a total response rate of around 15%, which was comparable to that of other studies of this nature (Mabert, Soni et al. 1999) and judged acceptable given the time and effort required to complete the questionnaire. Descriptive statistics for this sample are reported in Table 1.

Number of companies	82
Europe	53
Outside Europe	29
Project duration (months)	7.05
	(13.62)
Number of employees affected	711
	(2008)
Number of modules installed	7.03
	(3.07)
Number of sites involved	7.95
	(18.71)
Percentage of process supported	0.63
	(0.26)
(Standard deviation in parentheses)	

Table 1: Descriptive statistics

Given the nature of the study we paid particular attention to verify whether the sample retained for statistical analysis was representative both of the companies to which the questionnaire was administered and of the entire population of SAP customers in the three industry meta-sectors retained (process industries, discrete and consumer industries). As we did not have sufficient demographic data to carry out statistical tests for all the companies in the population, we analyzed the representativeness of the sample by means of an alternative approach. As a first step we compared the characteristics of our final sample to those of the population of SAP customers.

	2000		2002	
	MEuro	%	MEuro	%
Total (process, discrete, consumer)	3911	62%	4601	62%
Process industry	1366	34.93%	1537	33.41%
Discrete manufacturing	1549	39.61%	1764	38.34%
Consumer products	996	25.47%	1300	28.25%
Other	2354	23%	2812	23%
TOTAL	6265		7413	

Table 2: SAP revenue breakdown by sector (source: SAP AG annual report)

A comparison of SAP revenue breakdown by sector (Table 2) and of the sample of companies retained for the statistical analysis (Table 3) provides some preliminary insights. First, from the analysis of SAP revenue breakdown (Table 2) it can be evinced that the three meta sectors chosen for our research accounted for about 62% of SAP revenue, both in 2000 and 2002. This supported our choice to focus on these categories as the most representative of the ERP market. It is also worth noting that the discrete and the process industries account for the largest proportion of revenue, with consumer industries being however the fastest-growing sector.

	Sample of respondents (All countries)	
Process industry	24	29.27%
Discrete manufacturing	29	35.37%
Consumer products	29	35.37%
TOTAL	82	

Table 3: Sample breakdown by sector (all countries)

The sample of companies retained for the statistical analysis (Table 3) reflects quite closely the characteristics of the population of SAP customers in the three "meta-sectors" retained, with the only difference that consumer industries seem to be slightly over-represented. However, this difference can be easily explained by the fact that companies involved in the manufacturing or distribution of consumer products are on average smaller (and therefore likely to have lower ERP spending) than firms in the process and discrete industries[15]. As a result, the contribution of these companies can be proportionally larger when measured in terms of number of firms than when assessed with respect to the revenue they generate for SAP. This should explain the differences observed between the values in Table 2 and those in Table 3.

This conjecture was also confirmed by a more detailed comparison between the populations of French and Italian companies (for which we had industry sector data) and the sub-sample of companies in these two countries that returned our questionnaire. A first glance at Table 4 suggests indeed that the two groups match quite accurately.

	Population (Italy and France)		Sample (Italy and France)	
Process industry	72	33.33%	12	37.50%
Discrete manufacturing	79	36.57%	10	31.25%
Consumer products	65	30.09%	10	31.25%
TOTAL	216		32	

Table 4: Population and sample breakdown by sector: Italy and France

As a second step we analyzed more formally the Italian sample, for which we had precise demographic information (number of employees) that enabled us to carry out statistical tests. The population included 110 companies (38 in the process industry, 43 in the discrete and 29 in the consumer industry), 15 of which returned the questionnaire. The comparison between the sample and the population shows that no statistically significant differences can be found between the two groups, at least with respect to the size of the companies. The F and the t-test reported in Table 5 suggest that neither the hypotheses of equal variances nor that of equal means could be rejected ($t = 0.11$ vs $t^{0.05} = 1.97$ and $F = 1.08$ vs $F^{0.05} = 2.18$, non significant at the at 5% level).

[15] For instance, this difference is evident and statistically significant (at the 10% level) in the Italian sample, for which we had more detailed information.

Combining the observations above it can be therefore concluded with a reasonable degree of confidence that the sample retained for statistical analysis is sufficiently representative of the population of R/3 users in the three "meta-sectors" included in the study.

	Population	Sample
# of employees	1466	1391
(st.deviation)	(2423)	(2324)
Observations	110	15
Df	109	14
F		1.09
T statistics		0.11

Table 5: Characteristics of Italian sample

Chapter 5

Behind ERP: IT driven performance changes in European and American Firms

5.1 Introduction

In this chapter we challenge the prevailing wisdom that the performance changes caused by an ERP adoption are a mere consequence of the system impact on the firm's information processing capabilities. The central tenet of our approach is that differences in the information processing capabilities cannot explain, by themselves, the large differences in operational performance observed across ERP adopters. Rather, we suggest that the latter stem from the fact that the system influences the value creating mechanisms of the firm by altering its ability to generate effective operational routines. Drawing from the theory of dynamic capabilities we describe the mechanisms through which business organizations achieve superior performance and we identify the fundamental enablers of these mechanisms at the operational level. We also describe how IT-driven changes of these pillars may help explain the performance differences observed across IT adopters and how some characteristics of the organization and of the firm's operating environment may play a moderating role in the process.

5.2 Value creating mechanisms and the dynamic capabilities construct

5.2.1 Nature, genesis and operational attributes of dynamic capabilities

Management scholars have extensively investigated the sources of profitability of business organizations. The resource-based view of the firm (Penrose 1959; Prahalad and Hamel 1990; Barney 1991) and theory of dynamic capabilities (Leonard-Barton 1992; Pisano 1994) recognize that business success derive primarily from the firm's "ability to integrate, build and reconfigure internal and external competencies to address rapidly changing environments" (Teece, Pisano et al. 1997). At the core of the construct is the idea that when the competitive landscape evolves rapidly and unpredictably an organization can achieve competitive advantage only if it can promptly respond to the changes in its operational environment.

We suggest that the operational impact of an ERP implementation stems from the fact that the system interferes with the cognitive mechanisms through which the firm generates these capabilities. Unfortunately, although quite well established and widely used by strategy researchers, the dynamic capabilities construct has remained quite abstract and it has received little empirical verification. This weakness is partly due to the fact that it lacks clear measures. The existence of dynamic capabilities has been ascertained only indirectly, with respect to their supposed influence on the financial bottom line of the firm. Under this logic, companies that performed well in turbulent environments have been posited to possess dynamic capabilities, regardless of whether these competences were somehow reflected in the actual properties of the firm's operational routines.

Conversely, drawing upon the manufacturing strategy paradigm that recognizes the importance of process-level competences as a source of competitive advantage (Skinner 1974; Clark 1996; Skinner 1996) we suggest that the existence of dynamic capabilities should be observable at the operational level. To demonstrate that this is the case we adopt a more precise definition of the construct and we relate it to the three-core framework proposed by Swanson (1994) and discussed in chapter 1. Following Zollo and Winter (2001), we define a dynamic capability as a "learned pattern of collective activity through which the organization systematically generates and modifies its operational routines in pursuit of improved effectiveness" (Zollo and Winter, 2002: p. 10). By "operational routine" or "business process[16]" we indicate the combination of a structured sequence of basic tasks and the resource allocation schemes necessary to the execution of these tasks through which a firm accomplishes a specific business objective (e.g. the selection of a supplier, the replenishment of its inventory, etc.).

The above definitions imply that - whenever a feedback from the external environment signals to the firm that the routines currently in place no longer accomplish their objective in an effective fashion, an organization that possesses dynamic capabilities should be able to promptly reconfigure the task sequence and/or to reallocate the resources dedicated to its execution so as to restore and possibly improve operational effectiveness. The "systematic" nature of the capability also

[16] We use the two terms interchangeably. They both denote the combination of a group of connected activities (tasks) and the individuals (resources) who perform those activities.

implies that this prompt adaptation should not be the outcome of blind "firefighting", but it should rather be based on a consistent cognitive model that suggests the firm what the best configuration should be for a given external environment.

Following the above conceptualization, the three organization's cores used to classify IT systems (IS, administrative and technical/process) can also be seen as natural supporting pillars of the adaptation process at the operational level and be used to ascertain the existence of dynamic capabilities. First, the technical/process core is obviously a pillar, because "generating or modifying operational routines" necessarily implies the redesign of basic tasks (or at least the reconfiguration of their sequencing). The administrative core is also a key element, as the very same modification of operational routines would not be possible without an appropriate redeployment of the organizational resources that underlie the execution of tasks. Finally, although often overlooked by scholars in this area, the IS core is equally a critical enabler of adaptation: the latter is possible only if the firm receives a timely and accurate evaluative feedback from the external environment, which is needed both to initiate the process and to evaluate the effectiveness of the modified routines vis à vis the modified external environment. Needless to say, this ultimately depends on the quality of the systems devoted to information processing, i.e., on the IS core.

In line with the above conceptualization one would expect that the adoption of a technology that alters the dynamic capabilities of a firm would be signaled by the occurrence of changes in the three critical enablers above even before than this impact produces changes in the financial indicators. By the same argument, we would also expect that the adoption of a technology that affects one or more of these enablers should modify the firm's dynamic capabilities (or at least it should modify the firm's ability to exploit them) and it should ultimately produce an impact on operational performance. Based on this rationale, we suggest that the differences in operational performance observed across ERP adopters can be explained by examining the magnitude of the changes produced by the ERP implementation on the critical enablers of adaptation.

5.3 Impact of ERP adoption on dynamic capabilities

One of the most widely accepted views about ERP systems suggests that - by improving the timeliness and the accuracy of information inside the organization, the adoption of this technology would enable a firm to react more promptly to market changes, thereby *ipso facto* facilitating the adaptation process that is at the basis of the dynamic capability construct and consequently generating operational improvements. From the above viewpoint, this would be tantamount to saying that an ERP system merely affects the IS core of an organization and, furthermore, that its impact on operations is necessarily positive.

Conversely, we challenge this view and we suggest that an ERP adoption modifies the firm's ability to adjust its operational routines not only through its direct impact on the firm's information processing capabilities (i.e. on its IS core), but also through its influence on the process and administrative cores. We also suggest that it does so by interfering with the cognitive mechanisms through which the firms generate dynamic capabilities and its ability to redesign processes and to reallocate organizational resources when modified market conditions require so.

Scholars have suggested that the ability to "systematically generate and modify operational routines" does not arise spontaneously. It is the result of a knowledge evolution process that occurs through a "variation-selection-replication-retention" cycle and that is supported by *deliberate* investments in experience accumulation, knowledge articulation and knowledge codification (Zollo and Winter 2001). Through this cycle the firm explores new operational routines (i.e. new tasks sequences and new resource allocation schemes), submits them to market evaluation and, finally, retains the ones that prove to be most efficient. However, there is a major trade-off associated with investments in knowledge articulation and, especially, codification, which has important organizational consequences. On the one hand, investments in these activities accelerate the understanding of cause-effect relationships and facilitate the actual implementation and the replication of the newly discovered procedures. On the other hand, the articulation and, especially, the codification of knowledge also "increase the organizational inertia consequent to the formalization and structuration of task execution" (Zollo and Winter 2001, p. 343), thereby hampering the ability to promptly respond to market changes.

The delicate balance among these different knowledge investments affects the capability-building mechanisms of the firm, the nature of these capabilities and, ultimately, the ability of the organization to generate operational improvements. As a consequence, any technology innovation that requires or generates investments in knowledge articulation and codification, and regardless of the main purposes that initially motivated its adoption, also modifies the genesis, the evolution and the effectiveness of dynamic capabilities and has important consequences for the profitability and the operational effectiveness of the firm.

We suggest that an ERP implementation is precisely such a technology. Besides its ascertained structural impact on information processing capabilities (i.e. its impact on the IS core), an enterprise system alters the knowledge evolution cycle through which a firm generates dynamic capabilities. This is the result of two distinct phenomena, whose relative magnitude depends upon the particular implementation strategy chosen by the adopter.

On the one hand the implementation of the "best practices" contained in the software library is *de facto* a knowledge codification process that forces the ERP adopter to increase the level of structuration of its processes. This knowledge codification effort is expected to increase the operational *efficiency* of the firm (at least if the external environment for which the processes were originally optimized remain unchanged). However, the structuration of the operational routines and the resulting increase of complexity that stems from the very same logic of the software may impede further modifications of the newly designed routines, thereby hampering the variation phase in the knowledge evolution cycle and reducing the firm's adaptive capacity. On the other hand, if properly leveraged and continued even after the live date, the business reengineering process required to implement the system is likely to foster the exploration of new operational procedures, hence facilitating the variation phase in the knowledge evolution cycle and increasing the firm's adaptive capacity.

The relative contribution of these two antithetical effects depends upon the particular implementation strategy (especially on whether the firm decides to invest in continuous improvement efforts after the live-date) and recalls the trade-off between exploration and exploitation (March 1991). Hence, the ultimate impact exerted by the system on the firm's operational effectiveness will be contingent on the fit between the strategy chosen and the particular characteristics of the environment where the firm operates (namely if it requires continuous adaptation and process flexibility rather than exploitation and process efficiency).

We suggest that, whatever the prevailing effect is, the combination of these two impacts (change of process efficiency and process flexibility), together with the accompanying increase of the firm's information processing capabilities determine the change in the indicators of operational performance observed after adoption. This is synthesized by the following:

Proposition 1: *The implementation of an ERP system exerts a latent impact on the capability-generating mechanism of the adopter, which produces observable changes in the three enablers of the firm's adaptation process at the operational level. In turn the changes occurred in these enablers determine the changes in the indicators of operational performance typically observed after the implementation of an ERP system.*

The specific nature of these changes and their expected impact on the firm's operational performance will be further précised in the following paragraphs, based on the results of direct field observations.

5.4 External and internal contingencies and moderating factors

Notwithstanding its expected "structural" (i.e. system-specific) effects on the firm's ability to generate dynamic capabilities, the ultimate impact of an ERP system on the operational effectiveness of a business organization is contingent on the attributes of two "metasystems" in which the software implementation process is embedded (Figure 5). The first metasystem is the organization itself, intended as the structured social system composed of the individuals who need to modify their consolidated working habits to spouse the new procedures "imposed" by the ERP best practices. The second metasystem is the external environment where the firm operates, which - by submitting the newly designed routines to an evaluation, ultimately determines whether these routines are appropriate to respond to the specific challenges that it poses.

Figure 5 ABOUT HERE

5.4.1 Impact of organizational attributes

The implementation of complex IT systems does not occur in a vacuum. It takes place within a structured social system, composed of individuals with codified behaviors, working habits and tacit or explicit routines that were created and shaped *before* the adoption of the new technology. The radical modification of these codified behaviors – which is necessary to accommodate the new system, generate cultural and organizational clashes, which are often cited among the primary culprits for the failure of an ERP project. The fact that organizational issues play a critical role in ERP implementations is indeed well acknowledged and it is substantiated by abundant anecdotal evidence. Conversely, from a theoretical viewpoint it is less clear what specific organizational traits generate these problems and why.

We suggest that the organizational attributes that most affect the ERP implementation are those that interfere with the firm's adaptation process, i.e. the ones that facilitate or hamper the organizational changes demanded by the software adoption.

Since long ago organization theorists have recognized that bureaucracies are a necessary evil. On the one hand they are useful to limit coordination costs and to increase task performance, particularly in a manufacturing environment (Deming 1986; Schonberger 1986) as well as to reduce role ambiguity (Nicholson and Goh 1983). On the other hand they tend to de-skill employees, to stifle creativity and to decrease the predisposition to innovate (Bonjean and Grimes 1970; Kakabadse 1986; Arches 1991). Hierarchy and excessive formalization may exert a particularly negative impact when they are embedded in a coercive logic (Adler and Borys 1996; Adler 1999). A coercive bureaucracy uses task formalization to impose conformity to existing procedures and to prevent from deviation from standardized routines. Conversely, a bureaucracy that displays enabling characteristics (the opposite of coercive) uses the same task formalization as a tool to encourage employees to search for new and more effective solutions. In this environment formalization is meant to accelerate learning and to facilitate continuous improvement rather than conformity and compliance.

We conjecture that the ability to modify organizational routines, which underlies the whole dynamic capability construct and ultimately influences the success of an ERP project, can be significantly affected by the nature of the organization in which the new technology is implemented and in particular by its degree of structuration. As empowerment and the employees' predisposition to innovate are a necessary condition to modify organizational routines and to increase process flexibility and as these properties depend on the attributes of the organization we propose the following:

Proposition 2: *The ex-ante degree of structuration of the organization in which the ERP system is implemented moderates the primary impact that the technology exerts on the operational effectiveness of the adopter.*

5.4.2 The impact of the external operational environment

The external environment where the firm operates provides the evaluative feedback through which the organization assesses the effectiveness of its operational routines vis à vis the requirements of that particular environment: the same routine may exhibit different degrees of effectiveness depending on the attributes of the environment where it is executed. There are few doubts that dynamism (Miller 1987) - also referred to as turbulence, instability or "clockspeed" (Fine 1998) - is one of the most fundamental dimensions that distinguish a market and, indirectly, influence the success or the failure of a business model. Recently, researchers have also posited and verified empirically the occurrence of "a positive association between the clockspeed of an industry segment and the speed of the internal clock that paces the internal operations of a business unit in that segment". (Mendelson and Pillai, 1999, p. 8). Typically the faster the clockspeed of the industry segment, the faster the pace of the internal operations. The resource-based view has also recognized the importance of different environmental conditions for the genesis of dynamic capabilities, and has examined the impact of different levels of market dynamism on this process.

Following (Eisenhardt and Martin 2000) we portray two antithetical scenarios. In *moderately dynamic markets* changes occur at a slow pace and along predictable paths. The industry structures are relatively stable, market boundaries are clearly defined and the major customers and competitors are quite well known. Hence, organizations that operate in these environments can obviously heavily rely on previous experience to optimize their operational routines, because the environmental conditions under which this knowledge was developed still hold. Investments in knowledge codification are thus expected to be highly valuable.

Conversely, in *faster business environments*, changes occur at a higher pace and, especially, along paths that cannot be easily predicted. The industry structure is subject to continuous modifications, successful business models are fundamentally unclear and new players continuously replace old business partners. In these circumstances organizations cannot rely on existing knowledge to optimize their operational routines, as these were developed in an environment that has considerably changed afterward. The firm needs to update rapidly *both* its operational and learning routines and it requires process flexibility to achieve this objective. Thus, any action that increases the inertia of the system can be intrinsically hazardous. Investments in knowledge codification and process structuration are therefore expected to be less effective, if not even dangerous.

The knowledge investments produced by ERP adoption and the process structuration efforts required by the very logic of the system are obviously expected to be particularly valuable in relatively stable environments. However, the very same features that increase the effectiveness of process may also reduce their flexibility, as investments in knowledge codification decrease the firm tendency to modify organizational routines. Albeit this is not particularly dangerous when the environmental turbulence is low, it may well prove to be risky when the competitive landscape evolves rapidly. Mindful of this characterization we suggest the following:

Proposition 3: *The impact of the ERP-driven process changes on the firm's operational effectiveness is moderated by the degree of turbulence of the firm's operational environment*

The three propositions above can be combined together to derive the conceptual framework sketched in Figure 6. We expect that the changes observed in key performance indicators after ERP adoption are best explained by changes occurred in three fundamental indicators of operational excellence at the level of the basic firm's processes, and that the attributes of the adopting organization and the degree of turbulence of its operating environment to exert a moderating effect. This stylized framework constituted the point of departure for our empirical analysis and it was used to derive a set of more precise hypotheses that could be tested statistically.

Figure 6 ABOUT HERE

To examine the mechanisms through which the adoption of an enterprise system affects the operational effectiveness of a firm we proceeded in two stages. First we operationalized the variables necessary to test our model. Towards this end, we used factor analysis to provide a more precise characterization of the theoretical constructs discussed above (operational measures of dynamic capabilities and attributes of the bureaucracy). As a second step, we used the variables derived above in a regression analysis to examine: i) whether the ES-driven changes could explain the variation in key performance indicators observed in each business unit after the introduction of the system and, ii) whether the internal and external environment of the firm played a moderating role in this process. The data used to test the model hev been collected by means of the procedure described in chapter 4. After eliminating questionnaires with missing values and outliers, the sample contained 69 usable responses.

5.5 Operationalization of constructs

5.5.1 Operational antecedents of dynamic capabilities

Our first objective was to submit our operational conceptualization of the dynamic capability construct to an empirical verification and to derive more precise measures for the operational enablers of adaptation that could be used in regression analysis. From the semi-structured interviews conducted with industry representatives we identified eight key intermediate process and organizational elements linked to Swanson's three-core framework (Swanson 1994) that had been typically affected by the introduction of an enterprise system (or whose improvement had been one of the primary objectives of its adoption). These are: the accuracy, the timeliness and the homogeneity of information inside the organization (1-3); the amount of time and resources necessary to execute tasks (4-5) and the ability of the organization to deal with unexpected events, to reallocate resources across functions and to modify processes (6-8).

To evaluate the impact of ERP adoption on these variables, in the questionnaire we asked respondents to consider a representative business process in their unit that had been profoundly transformed by the ES introduction and to evaluate on a 7-point likert scale the extent to which the eight parameters above had changed after the adoption (we considered again a time interval of one year after the live date as a reference).

To extract the underlying dimensions of change from these impact factors we applied factor analysis to the eight items[17] (Table 6 displays the rotated factor patterns, the commonality and the proportion of variance explained by each factor for the pooled sample). The eight items loaded on three factors[18] that, together, explained about 70% of the variance in the sample. The questions related to information attributes loaded consistently on one factor, which we simply named "*quality of information*". This suggests that the individual components of this construct often vary *together* as a result of an ES adoption (or that respondents have difficulty to discriminate across different types of information change).

The remaining items loaded on two distinct factors. The first included resource allocation and task execution time whereas the second contained the ability to manage non-routine task and to modify processes and organizational structure. In recognition of the fact that they refer respectively to the ability to use resources efficiently and to redeploy them rapidly to handle non-routine events and in line with our initial conceptualization we named these factors *process efficiency* and *process flexibility*.

The "ability to integrate, build and reconfigure internal and external competencies to address rapidly changing environments" is guaranteed only by the simultaneous existence of these three fundamental enablers of the adaptation process: *information quality*, *process efficiency* and *process flexibility*. Together, they form the

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[17] Kaiser's Measure of Sampling Adequacy was above .60 for each individual variable considered. Hence, all items were retained for factor analysis (Kaiser 1970).

[18] Throughout all the analysis we used the mineigen criterion to select factors (i.e. we retain only factors whose eigenvalue was larger than 1).

primary constituents of the dynamic capability construct at the operational level and are expected to be a major driver of operational excellence.

Variable	Quality of information	Process flexibility	Process Efficiency	*Communality*
Accuracy of information	0.79	-0.12	-0.09	0.65
Timeliness of information	0.73	0.03	0.03	0.54
Homogeneity of information	0.72	-0.19	-0.14	0.58
Job rotation	-0.23	0.86	-0.06	0.80
Process changes	-0.10	0.80	0.18	0.69
Management of non-routine tasks	0.05	0.68	0.34	0.59
Task resource use	-0.03	0.09	0.89	0.81
Task execution time	-0.14	0.19	0.85	0.78
% of variance explained	35%	18%	15%	68%

Table 6: Factor analysis for the effect of ERP adoption on process attributes

To validate our measures, we repeated the analysis on each of the two regional sub-samples separately (Europe and North America). The factors obtained from the two subgroups are consistent with those of the pooled case and are not reported here. As we wanted to obtain clean measures that could be used in regression analysis, we retained for each dimension the item that had the highest loading on each factor in the pooled sample (respectively: accuracy of information, ability to rotate jobs across employees and task execution time). This preliminary analysis enabled us to refine proposition 1 and to propose a set of specific testable hypotheses.

First and foremost, mindful that implementation of an ES permits the elimination of redundant data, their harmonization and it requires their storage in a unique repository that can be readily accessed, we suggest that:

H1a: *Regardless of its impact on process efficiency and process flexibility, the adoption of an ERP system is expected to consistently improve the quality of the information inside the host organization;*

Second, we also observed that the templates contained in the software library are extremely detailed processes derived from the actual practices of many leading firms worldwide. As such they are entirely based on existing and codified knowledge, which typically facilitates the execution of basic tasks. However we also noted that, since the very same process of configuring the software is typically extremely long and costly, the firm may tend to operate in accordance to the best practices selected for the longest possible amount of time, even when this no longer optimal thereby de facto reducing flexibility. Therefore we propose:

H1b: *Regardless of the impact on information quality, the increase of process efficiency observed in organizations after ERP adoption is expected to be proportionally larger than the increase of process flexibility observed in the same period;*

Finally, as we suggested that an ERP adoption impacts the dynamic capabilities generating mechanism and that this impact is observable at the level of the operational enablers of adaptation, we also expect that the changes produced in these basic variables be reflected in the performance indicators used to monitor the effectiveness of the processes that they support. Therefore we propose:

H2a: *Controlling for project success, the larger the improvement of the information quality generated by an ES implementation, the higher the improvement observed in the firm's key performance indicators after adoption;*

Hp 2b: *Controlling for project success the larger the increase of process efficiency generated by an ES implementation, the higher the improvement observed in the firm's key performance indicators after adoption;*

Hp 2c: *Controlling for project success the larger the increase of process flexibility generated by an ES implementation, the higher the improvement observed in the firm's key performance indicators after adoption;*

5.5.2 Moderators

5.5.3 Organizational characteristics

Our second operational objective was to provide a more precise formulation for our generic statement that the attributes of a bureaucracy moderate the structural impact exerted by an enterprise system on the antecedent of dynamic capabilities. Obviously, this also required a more precise characterization of the organizational attributes.

We followed an approach similar to the one described in the previous paragraph. As a first step, during the structured interviews that preceded the administration of our questionnaire, we asked managers to describe what attributes of their organization they felt to have the largest impact on the implementation of the system and, especially on its daily utilization. These attributes were then operationalized in the questionnaire through four specific items coded on a 7-point likert scale: i) the existence of a structured hierarchy with a clear separation of roles, ii) the extent to which tasks and responsibilities are clearly defined inside teams, iii) the use of manual, written documents and other formal procedures to facilitate the execution of tasks and, finally, iv) the extent to which the use of cross-functional teams was common in the organization (which reflects the firm attitude to be process-oriented as opposed to function-oriented). In addition, as we feared that many respondents could overemphasize the degree of "bureaucratization" of their organization, we added a fifth question that dealt with the extent to which salaries are dependent on the formal position held (which was expected to measure the previous construct in a less subjective fashion).

We initially applied factor analysis to all the five questions. However, as the item that measured the frequency of use of cross-functional teams exhibited an unacceptable (<.50) level for the Kaiser's measure of sampling adequacy (Kaiser, 1970) we excluded it from the analysis and applied the procedure to the remaining four items.

The four items loaded on two factors (that together accounted for about 75% of the total variance) and displayed a limited degree of cross loading. We also repeated the analysis for the three samples to cross validate the measures (Table 7[19]).

Although all questions were somehow related to what people often refer to as "bureaucracy", they clearly reflected two specific facets of this construct, in line with the distinction between coercive and enabling bureaucracies developed in (Adler and Borys, 1996).

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[19] Again, for purposes of conciseness we report only the results for the overall sample.

The first dimension refers to the fact that a bureaucracy is often associated with a non-flexible organizational structure, where the role and the responsibilities are defined "a priori" by the formal position held and where changes are hampered by a high level of organizational inertia. Accordingly, we labeled the first factor *organizational rigidity*.

Variable	Rigidity	Codification	*Communality*
Structured hierarchy	0.82	0.30	0.76
Salaries dependent on formal position	0.89	0.00	0.80
Use of manuals and written procedures	0.30	0.79	0.72
Clear definition of responsibilities	0.00	0.88	0.78
% of variance explained	50%	26%	76%

Table 7: Factor analysis for organizational attributes.

Conversely, the second dimension – that we named *knowledge codification*, reflects the extent to which the organization relies on formalized models and routines to facilitate the execution of tasks (as opposed to a model where employees make decisions based on their personal judgment or past experience). Not surprisingly, the item that addresses the use of cross-functional teams was negatively correlated with the one that deals with the reliance on formalized procedures for the execution of tasks, as this practice does not typically require the use of cross-functional teams (where team members are often confronted with new problems that require experiential learning, organizational adaptation and ad-hoc problem-solving rather than off-the-shelf solutions based on standard routines).

Relying on codified knowledge may have antithetical effects in the context of an ERP adoption. On the one hand extremely codified routines may generate organizational inertia and prevent the organization from properly leveraging the new ERP-based processes. On the other hand it is also true that codified knowledge diffuses more rapidly reduces causal ambiguity and favor the assimilation of new working practices.

Once again, the refined characterization derived from the above analysis enabled us to better specify our initial conjecture that the attributes of the firm bureaucracy play a role in explaining the performance changes observed after ES adoption. Drawing upon the above categorization we suggest that:

H 3a*: Controlling for project success and for process and information changes, the higher the degree of organizational rigidity of the ES adopter, the lower the operational improvements observed after the ES implementation;*

H 3b*: Controlling for project success and for process and information changes, the higher the degree of knowledge codification displayed by the ES adopter in the pre-ERP processes, the higher the operational improvements observed after the ES implementation;*

5.5.4 Clockspeed

To operationalize the market dynamism construct we used a modified version of the clockspeed measure proposed in (Mendelson and Pillai 1999), which is composed of the following variables: i) the total duration of the product life cycle[20], ii) the proportion of total revenue that is generated from products introduced in the market in the preceding twelve months; iii) the rate of decline of the prices of the main input materials.

However, due to the difficulty in obtaining reliable data for the third variable, we decided to exclude it from our analysis and to use a simpler 2-item measure obtained as a linear combination of the first two. The choice was justified by the fact that in the original Mendelson and Pillai's scale the three items loaded equally on the single clockspeed factor. Moreover, to further validate our choice we tested the dimensionality of this revised two-item scale through a confirmatory factor analysis on the three samples (which confirmed that the two items heavily load on a single factor and explain between 69% and 73% of the total variance).

Mindful of the above discussion about the influence of market dynamism on the effectiveness of dynamic capabilities, we can now further develop proposition 3 and propose the following testable hypotheses:

[20] for companies that deal with multiple products respondents were asked to refer the product with the largest sales volume

H4a: *Controlling for project success, process and information changes and for the type of bureaucracy of the adopter, the higher the degree of turbulence of the firm's operating environment, the larger the positive impact of process efficiency on key performance indicators.*

H4b: *Controlling for project success, process and information changes and for the type of bureaucracy of the adopter, the higher the degree of turbulence of the firm's operating environment, the larger the positive impact of process flexibility on key performance indicators.*

5.5.5 Control variables

5.5.5.1 Project execution

The first variable that we decided to control for deals with project execution. Many practitioners and most of the popular press often associate the success or failure of ERP projects with the deviation of the project from its planned budget or schedule. By the same token, numerous academic studies on ERP that take a project management perspective have used these variables as a proxy for evaluating the success or the failure of the implementation.

Thus, although our primary conjecture was that the ultimate impact of an enterprise system adoption is related to its impact on the operational antecedents of dynamic capabilities, we could not exclude a priori the hypothesis that a successful project execution may facilitate the realization of superior operational performance. To control for this factor, in the questionnaire we have simply asked respondents to evaluate on a 7-point likert scale the extent to which the actual project budget and duration deviated from the stated objectives. For purposes of parsimony we have then computed an aggregated measure of project management success as a linear combination of the two items and used this in our analysis to control for the quality of project execution.

5.5.5.2 Project scope

Our second control variable considers the impact of project scope. Obviously, we expect that the modifications induced by the system and – ultimately, its effect on the firm key performance indicators, be proportionally more visible in companies that had broader implementations.

Given that all the companies in our sample implemented the same basic software, but they differed with respect to the types of specific R/3 modules adopted, the simplest solution to control for project scope would have been to consider the number of modules adopted. However, after our preliminary interviews and after further discussion with company representatives, we realized that this was not a valid measure of project penetration. For instance, vast organizations that adopt a large number of modules may still be superficially affected by the system and have few employees being actual user, whereas small firms that implement only one module to support their core process may be affected to a much larger extent. For this reason we used a more general measure of project penetration, viz: the proportion of the firm's processes that were supported by R/3 at the time of the response to the questionnaire.

5.5.5.3 Project duration

As a third step we decided to control for project duration, which was measured as the number of month elapsed between the initiation of the project and the "live date". This variable is a proxy for the intensity of efforts undertaken by the firm during the implementation of the software (typically longer projects are more likely to be associated with radical business process re-engineering activities), although it is worth stressing that it is not necessarily an indicator of project success (an ERP implementation may be long simply because the project escalate). This is confirmed by the fact that the variable is very weakly correlated ($\rho = 0.002$ and insignificant) with our primary measure of project excellence, deviation from planned budget and schedule.

5.5.5.4 Industry and region of establishment

Finally – as this factor could be associated with different implementation strategies that lead to different impacts on operations - we also decided to control for the geographical regions where the companies are established. We accounted for this factor by means of a dummy variable, which was set equal to 0 if the company was located in Europe and equal to 1 if it was located outside Europe.

5.5.6 Dependent variable

Our final step consisted in defining an operational measure for our dependent variable. Given that our objective was to examine the impact of ES adoption on operational measures of performance, (i.e. on variables directly linked to the fundamental business processes supported by the Enterprise System) we used Swanson's three-core model to select four indicators related to excellence in the IS, the administrative and the technical/process core. These are: i) software maintenance and upgrading costs, ii) administrative and accounting costs, iii) financial closing time, iv) customer response time.

The four items were again operationalized through a 7-point likert scale that measured the extent to which each indicator had improved or deteriorated one year after the live date with respect to the pre-R/3 epoch.

The choice of a likert scale for measuring changes in our dependent variable (as opposed to a purely quantitative instrument) was finally retained after a pre-test of the questionnaire, for three main reasons. First, we wanted to account for the relative magnitude of the observed change with respect to the initial company expectations (i.e. with respect to their stated goals) rather than to evaluate them in absolute terms. Second, realizing a given improvement in a particular area (e.g. distribution) is proportionally more difficult for companies that already have top quality processes in that very same area[21]. Using a quantitative scale would not consider this aspect, which is conversely correctly taken into account by a subjective evaluation. Finally, after pre-testing the preliminary version of our questionnaire, we realized that the use of a quantitative measure would have significantly increased the response time and consequently it would have dramatically decreased the number of answers.

To address the potential bias that would derive from the fact that respondents tend to give more accurate answers to questions that refer to their own areas of expertise, we computed an aggregated measure of operational performance obtained as the average of the four individual items listed above. We used this measure as our main dependent variable throughout the rest of the analysis.

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[21] For instance, a company that competes in a market highly sensitive to supply chain responsiveness and that increases its fill rate from 98% to 99% can judge this improvement as important as that of another firm that competes in a different market and for which the same indicator improves from 70% to 80%.

To validate our choice we performed a confirmatory factor analysis on the four key performance indicators (Table 8). The four items did load on a single factor, hence confirming the unidimensionality of the variable and further supporting our choice to use the four-item scale as a single dependent variable in the regression analysis.

	Eigenvalue	Variance explained
Factor 1	1.84	0.47
Factor 2	0.90	0.22
Factor 3	0.74	0.18
Factor 4	0.53	0.13
	KPI change	Communality
Software maintenance cost	0.72	0.52
Administrative and accounting cost	0.78	0.62
Customer Response time	0.47	0.22
Financial closing time	0.69	0.47

Table 8: Confirmatory factor analysis for changes in KPIs

5.6 Impact of ES-induced changes on key performance indicators

5.6.1 Magnitude of ERP-driven process changes

The data necessary to test the above hypotheses were collected by means of the procedure described in chapter 4. After eliminating 6 outliers and 7 incomplete questionnaires from the original set of answers, we remained with 69 valid responses that were suitable for statistical analysis (45 companies were located in Europe whereas the remaining 24 were based in North America).

As a preliminary step we wanted to get a feeling for the direct impact that ERP adoption had on the three "process-oriented" antecedents of dynamic capabilities identified above. To do so, we first examined the impact on information quality by conducting a t test on the mean of a new variable obtained by normalizing the original score to its mean (H$_0$: $\mu_{\text{information}} = 0$, H$_1$: $\mu_{\text{information}} > 0$). Similarly, to test for the hypothesis that ERP-driven increases in process efficiency are proportionally larger than increases in process flexibility we computed a new standardized variable, obtained as the difference between the normalized efficiency measure and the normalized flexibility measure described above and we conducted a one-tailed t test on its mean (H$_0$: $\mu_{\text{eff-flex}} = 0$, H$_1$: $\mu_{\text{eff-flex}} > 0$). Both tests led to the rejection of the null hypotheses, although the significance of the first one was several orders of magnitude larger than the second ($t_1 = 16.52$, with $p_1 < 0.001$; $t_2 = 2.54$ with $p_2 = 0.01$). Furthermore to evaluate the consistency of these impacts across firms, we conducted three one-tailed F tests between pairs of variables (quality of information vs. efficiency and flexibility, efficiency vs. flexibility) to test for differences between variances. The test was highly significant (at the 0.03% and 0.05% level) for both the comparisons that involved information quality (H$_0$: $\sigma^2_{\text{information}} = \sigma^2_j$, H$_1$: $\sigma^2_{\text{information}} < \sigma^2_j$ with j = efficiency, flexibility) but not significant for the comparison between the two process variables (H$_0$: $\sigma^2_{\text{efficiency}} = \sigma^2_{\text{flexibility}}$, H$_1$: $\sigma^2_{\text{efficiency}} < \sigma^2_{\text{flexibility}}$).

Altogether these results suggest the following considerations: i) ERP adopters exhibit a generalized increase of information quality and this increase is quite consistent across the firms in the sample; ii) when considering process variables, the efficiency improvements observed after adoption are proportionally larger than the flexibility improvements, although they exhibit similar variance; iii) the changes occurred in both the process variables display a higher variability than the parallel changes observed in the quality of information. In turn this suggests that whereas an adopting an ERP can often be a sufficient condition to improve the firm's information processing capabilities, it cannot guarantee – by itself – an improvement of its operational performance. This is influenced by a number of moderating factors (characteristics of the implementation process, organizational attributes, etc.) that should be carefully controlled during the implementation of the software.

5.6.2 Impact of process changes and contingency factors on key performance indicators

After this preliminary analysis we turned our attention to the two main research questions that we had outlined in the introduction, namely: i) whether the changes occurred in the process variables can explain the differences in key performance indicators observed across adopters (hypothesis 2) and ii) whether the internal and external contingencies (organizational attributes and market dynamism) have a moderating role and towards what direction they exert their influence (hypotheses 3 and 4).

	N	Mean	Std Dev	Sum	Minimum	Maximum
Project execution	69	4.23	1.19	291.54	1.50	7.00
Project Scope	69	0.64	0.25	43.83	0.15	0.98
Project Duration	69	12.96	6.73	894.00	3.00	36.00
Quality of information	69	5.85	0.93	403.52	2.00	7.00
Process Efficiency	69	4.56	1.33	314.58	1.00	7.00
Process flexibility	69	4.40	1.43	303.33	1.00	7.00
Organizational rigidity	69	4.55	1.53	313.67	1.00	7.00
Codification	69	4.15	1.70	286.29	1.00	7.00
Clockspeed	69	1.00	0.64	68.78	0.00	1.95

Table 9: summary statistics

To achieve these objectives we estimated a series of regression models using the aggregated measure of performance derived above as a dependent variable. A revised version of the initial model presented in Figure 6, inclusive of the findings of our empirical analysis is drafted in Figure 7.

As none of the variables in the model posed collinearity problems (the largest correlation coefficient was far below 0.5) and as no major theoretical reasons could suggested the occurrence of non-linear phenomena, we decided to use a simple linear model and to estimate it by means of ordinary least square analysis at the benefit of higher parsimony and higher efficiency of the estimators. The analysis of the residuals of all the regressions reported below supported our decision, as none of the error scatterplots deviated significantly from the null plot, thereby confirming both the inherent linearity of the phenomenon and the absence of heteroskedasticity.

	Correlation								
	1	2	3	4	5	6	7	8	9
Project Execution									
Project Scope	-0.06								
	(0.62)								
Project Duration	0.00	0.23							
	(0.98)	(0.06)							
Location	0.14	0.22	0.07						
	(0.26)	(0.07)	(0.57)						
Quality of information	0.23	-0.08	-0.02	-0.13					
	(0.06)	(0.50)	(0.89)	(0.28)					
Process efficiency	0.19	0.10	0.05	0.17	0.04				
	(0.12)	(0.39)	(0.71)	(0.16)	(0.72)				
Process flexibility	0.09	0.13	0.00	0.08	0.23	0.09			
	(0.44)	(0.28)	(0.98)	(0.52)	(0.05)	(0.45)			
Organizational rigidity	0.14	0.14	-0.04	0.14	0.15	0.17	0.38		
	(0.26)	(0.27)	(0.75)	(0.24)	(0.22)	(0.16)	(0.00)		
Codification	0.05	0.05	0.09	-0.06	-0.08	0.13	-0.14	0.26	
	(0.71)	(0.66)	(0.48)	(0.62)	(0.53)	(0.27)	(0.26)	(0.03)	
Clockspeed	-0.12	0.24	-0.08	-0.05	0.05	-0.22	0.17	-0.25	-0.30
	(0.31)	(0.04)	(0.50)	(0.70)	(0.70)	(0.06)	(0.16)	(0.04)	(0.01)

Table 10: correlation among variables

5.6.3 Process changes and control variables

To unveil the *direct* impact of main predictors on the aggregated measure of process excellence and we started by estimating the basic models (model 1-3):

$$\Delta KPI = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \qquad (1)$$

where after controlling for the firms' location, changes in operational performance ΔKPI are explained only by means of differences in the quality of project execution (x_1) in the degree of penetration of the system in the host organization (x_2) and in the duration of the implementation project (x_3).

This models represented a sort of "null" hypothesis that - regardless of the changes that occur in the three cores of the organization and regardless of the characteristics of the organization and of its operational environment, an extensive ERP implementation that is properly managed (on time and with no budget overruns) would guarantee performance improvements.

As a second step, to test the *direct* impact of the process-oriented measures of the dynamic capabilities construct we estimated a second set of models (models 4, 5 and 6) of the form:

$$\Delta KPI = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + +\beta_3 x_3 \sum_{i=3}^{n} {}_i x_i \qquad (2)$$

with n = 4, 5 6, where we progressively added to the basic model (3) the three explanatory variables related to the changes induced by the ERP on the three cores of the organization, namely: changes in information quality x_4, changes in process efficiency x_5 and changes in process flexibility x_6.

The results of this analysis are summarized in Tables 12-14. Table 12 and 13 report the unstandardized regression coefficients and the overall explanatory power (adjusted and non adjusted) of the main models retained. Table 13 displays the increase in R^2, the F ratios and the corresponding significance levels observed in each model after the inclusion of additional variables. The first interesting observation that emerges from the analysis is that the "null models" have virtually no explanatory power and it is not significant. Contrary to common wisdom, an effective project management and an extensive implementation cannot by themselves guarantee the achievement of operational improvements. In sharp contrast with most of the common fads that identify budget overruns and project delays as the primary culprit for the failure of an ES implementation, our analysis suggests that deviating from planned budget or schedule has virtually no *direct* influence on key performance indicators (coefficient never significant and always close to zero). Needless to say, this result does not imply that the management of an ES implementation has no influence *at all*. It simply indicates that – in order to be effective – these efforts should be focused on improving the true sources of operational excellence that emerge from the analysis below (i.e. the efficiency and the flexibility of the newly designed processes).

	Modell	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	4.70	4.12	4.09	2.85	1.92	1.95
	(13.38)***	(9.23)***	(9.08)***	(2.68)***	(2.12)**	(2.25)**
Project Execution	0.05	0.06	0.06	0.04	-0.02	-0.03
	(0.63)	(0.70)	(0.81)	(0.48)	(-0.30)	(-0.38)
Project Scope		0.37	0.44	0.46	0.32	0.20
		(0.98)	(1.12)	(1.17)	(0.96)	(0.63)
Project Duration		0.03	0.03	0.03	0.02	0.03
		(1.77)*	(1.78)*	(1.79)*	(2.04)**	(2.24)**
Location			-0.16	-0.12	-0.24	-0.27
			(-0.78)	(-0.58)	(-1.37)	(-1.61)
Quality of Information				0.13	0.12	0.07
				(1.28)	(1.37)	(0.76)
Process Efficiency					0.32	0.31
					(5.30)***	(5.40)***
Process Flexibility						0.14
						(2.61)***
DF	67	65	64	63	62	61
R^2	0.006	0.079	0.088	0.111	0.388	0.449
Adj. R^2	-	0.036	0.031	0.040	0.329	0.386
F Value	0.40	1.86	1.54	1.57	6.55***	7.11***
ΔR^2	-	0.073	0.009	0.023	0.277***	0.061***
N. of Observations	69	69	69	69	69	69

(t-statistics in parentheses: *= significant at 10%; **= significant at 5%; ***= significant at 1%)

Table 11: Direct impact of ERP-induced process changes on Key Performance Indicators

A similar argument holds for the case of our second control variable: project scope, which is also not significant in none of the models tested. This suggests that in our sample implementations of limited scope were seldom developed as "vanilla" projects. In the ERP jargon, these are superficial projects motivated by the need to solve local technical problems (such as the Y2K or, in Europe, the transition to Euro) and that do not permeate the organization profoundly enough to require an extensive BPR effort to streamline processes. Indeed, in the cases we analyzed, a limitation in project scope was not necessarily associated to a lack of effort to ameliorate processes.

After entering the first ERP-induced process change (changes in information quality) the model remains insignificant and has still virtually no explanatory power, thus leading to a rejection of hypothesis 2a ($R^2 = .11$, $\Delta R^2 = .02$ and insignificant). This result is in contrast with one of the reasons that most often motivate the adoption of an ERP system, namely the need to generate better information. Indeed, adopting an ERP system does improve the quality of information (92% of the companies in our sample reported improvements along this dimension). However, ameliorating the accuracy, the timeliness and the homogeneity of data is not a sufficient condition to produce the process and organizational changes necessary to improve the operational performance. It is only when effectively used to support the real drivers of process excellence that improved information can contribute to the achievement of operational effectiveness.

Conversely, the model becomes significant and it explains a significant amount of the overall variance of the sample when the two process-oriented variables are introduced, both independently and jointly ($R^2 = .388$, $\Delta R^2 = .27$ significant at the 1% level when process effectiveness is included; $R^2 = .449$, $\Delta R^2 = .061$ significant at the 1% level when process flexibility is also added). As argued in hypotheses 2a and 2b, the two process-related variables have a strong and positive impact on operational performance, and they do so consistently for all the models tested (i.e. even after entering additional variables). In particular the ability to reconfigure business and organizational processes has a large positive influence on key performance indicators and it naturally suggests itself as the primary measure of the dynamic capability construct at the operational level.

It is also worth stressing that – although not sufficient by itself to account for a significant amount of variance - project duration has a positive and significant impact in all the models tested. These supports our initial conjecture that long implementations are likely to be associated with serious BPR efforts and, in turn, contribute to generate operational benefits.

5.6.4 Impact of organizational attributes

Having identified changes in process efficiency and process flexibility as the two most critical variables that directly explain ERP-driven changes on KPIs, in the second part of the analysis we focused on the internal and external contingency factors that, according to the stylized modeled sketched in Figure 6, could exert a moderating effect on the direct predictors.

To ascertain whether the hypothesized moderating variables were simple predictors, quasi-moderators, pure moderators or homologizers[22] we adopted the procedure described in (Sharma, Durand et al. 1981; Arnold 1982), and we repeated it for the two groups of moderators retained in our model: organizational attributes and market dynamism. Accordingly for each possible moderating factor, we performed the following steps:

1. we estimated a "base model" without moderators and without the non-significant control variables (hereafter named model "a");
2. we estimated an "extended version" of the base model, where the hypothesized moderator was only introduced as a direct predictor (model "b");
3. we estimated a "complete version" of the moderated model, that included both the hypothesized moderator and its cross products with the direct predictors with which it was expected to have an interaction (model "c");

If significant statistical difference occurred only between models "*a*" and "*b*", the hypothesized moderating variable was retained as a pure *predictor*. If we observed significant statistical difference only between models "*a*" and "*c*" the moderating variable was considered as a *pure moderator* (i.e. it was considered to affect the dependent variable only through its effect on the coefficient of one of the direct predictors). If significant statistical difference occurred among all the three models, the variable was classified as a *quasi-moderator* (i.e. it was considered to affect the dependent variable both directly and indirectly). As at least one of the above cases occurred for all the models tested, it was never necessary to revert to subgroup analysis to assess whether the target variable was a homologizer (step 4 of the procedure). The results of this exercise are reported in Table 13 that displays

[22] Pure moderators and quasi moderators affect the form rather than the strength of a relation and are best detected by means of moderated regression analysis (MRA). However, whereas pure moderators have only an indirect impact on the dependent variable through their influence on the regression coefficient of the primary explanatory variable(s), quasi-moderators have both an indirect and a direct impact. Conversely, homologizers affect the strength rather than the form of the relation and are typically best detected by applying subgroup analysis (Sharma et al. 1981).

additional increments in R^2 and the corresponding F ratios for the most representative models retained.

	Model7	Model 8	Model 9	Model 10	Model 11
Intercept	1.885	1.580	1.698	1.526	1.947
	(2.240)**	(1.880)**	(1.960)**	(1.710)**	(1.690)**
Project Duration	0.026	0.023	0.023	0.024	0.021
	(2.340)**	(2.130)**	(2.070)**	(2.370)**	(1.920)**
Quality of Information	0.075	0.095	0.096	0.137	0.085
	(0.900)	(1.170)	(1.180)	(1.790)*	(0.990)
Process Efficiency	0.297	0.296	0.290	-0.054	0.296
	(5.260)***	(5.330)***	(5.090)***	(-0.420)	(5.010)***
Process Flexibility	0.139	0.196	0.205	0.524	0.210
	(2.560)***	(3.390)***	(3.410)***	(4.800)***	(3.440)***
Organizational rigidity		-0.110	-0.119	-0.084	-0.100
		(-2.000)**	(-2.070)**	(-1.550)*	(-0.790)
Codification		0.096	0.092	0.083	0.029
		(2.080)**	(1.950)**	(1.830)**	(0.310)
Clockspeed			-0.074	-0.130	-0.251
			(-0.580)	(-0.280)	(-0.480)
Clockspeed x efficiency				-0.280	
				(-3.190)***	
Clockspeed x flexibility				0.257	
				(2.610)***	
Clockspeed x rigidity					-0.012
					(-0.120)
Clockspeed x codification					0.056
					(0.780)
DF	64	62	61	59	59
R^2	0.421	0.474	0.477	0.566	0.482
Adj. R^2	0.385	0.423	0.417	0.500	0.403
F Value	11.630***	8.050***	7.950***	8.530***	6.110***
ΔR^2		0.053**	0.003	0.089***	
Number of Observations	69	69	69	69	69

(t-statistics in parentheses: *= significant at 10%; **= significant at 5%; ***= significant at 1%)

Table 12: Direct and indirect impact of ERP-induced process changes on Key Performance Indicators

It is important to note that - contrary to what asserted by some researchers – moderated regression analysis (MRA) is an appropriate technique to test for interaction effects, as it does not alter the test for significance of the interaction terms (Southwood, 1978). However, it is also important to recall that as it does alter the test for the other coefficients, the models that examine the impact of moderating variables must be evaluated only with respect to their overall significance and to the significance of the coefficient of the interaction terms.

The analysis suggests several interesting remarks. Theoretically, we would expect that the two organizational variables (rigidity and codification of procedures) would act as pure or quasi-moderators for the effect of process flexibility and efficiency on performance. Conversely, the first interesting and quite surprisingly outcome is that both variables emerge as *direct predictors* rather than as moderators of the changes in KPIs observed after the implementation of an ERP. ($\Delta R^2 = .053$ with $F = 6.45$ significant at the 1% level when the organizational variables are first added, whereas the increase was negligible and not significant when the cross products are also introduced in the model, either individually and jointly). Accordingly, to conduct further tests, we retained an extended version of our base model, with the two organizational attributes included as direct predictors. This model (model n.8 in Table 12) explained about 47% of the total variance in the sample and was significant at the 1% level.

The second interesting observation is that organizational rigidity and codification of procedures display an antithetical effect. On one hand, high degrees of organizational rigidity hamper the achievement of operational improvements, thus confirming our initial claim that this characteristic prevents a firm from redeploying its internal resources in an optimal fashion when the external environmental conditions require so.

On the other hand, and in line with our initial expectations, the degree of codification of procedures exerts a *positive* impact. In the particular circumstances of an ERP adoption this organizational trait is not necessarily an enemy. This result can also be interpreted in relation to the dichotomy between competence-enhancing and competence-destroying innovations (Tushman and Anderson 1986). Given that an ES implementation is *de facto* a knowledge codification process, companies whose knowledge repository was already extremely codified and structured in the pre-ERP era are more likely to perceive the innovation as a competence-enhancing rather than as competence-destroying one. Hence, they can rapidly profit from it to move towards a higher efficiency frontier. Conversely, organization whose pre-ERP culture was more fluid, less structured and whose operational routines were not based on codified procedures, are more likely to perceive an ERP as a competence-destroying technology, with negative consequences for performance, at least in the short or medium run.

		R^2	ΔR^2	F ratio
Quality of information	Model 3	0.088		
	Add quality of information	0.111	0.023	1.682
Process variables	Model 4	0.111		
	Add process efficiency	0.388	0.277	29.420***
	Add process flexibility	0.449	0.061	7.196***
	Model 4	0.111		
	Add process flexibility	0.21	0.099	8.146***
	Add process efficiency	0.449	0.239	28.194***
	Model 4	0.111		
	Add process efficiency and flexibility	0.449	0.338	39.873***
Organizational attributes	Model 7	0.421		
	Add codification and rigidity	0.474	0.053	6.449***
	Add cross products	0.474	0	0.000
Clockspeed	Model 8	0.474		
	Add clockspeed	0.477	0.003	0.367
	Add only cross products efficiency and flexibility	0.566	0.089	13.124***
	Add only cross products rigidity and codification	0.482	0.005	0.618
	Add cross products efficiency and flexibility, then codification and rigidity	0.572	0.006	0.897

(* = significant at 10%; * * = significant at 5%; *** = significant at 1%)

Table 13: Incremental changes in R^2 and test for moderating effect of contingency factors

5.6.5 Impact of market dynamism

Finally, we tested for the impact of market dynamism (clockspeed) by repeating the same 4-step procedure described above. To take into account the ascertained direct impact of organizational rigidity and codification of procedures, we began our analysis from the revised base version of our initial model (model 8), in which these two variables were already incorporated as direct predictors in the regression equation.

In contrast with what observed for the organizational variables and in accordance with the theory of dynamic capability, environmental dynamism emerges as a moderator of the effect of the process variables on performance rather than as a pure predictor. The revised base model (model 8) exhibits limited and insignificant increments in its explanatory power when the clockspeed variable is added as a direct predictor (ΔR^2 = .003 with F =0.37), whereas the explanatory power increases substantially and at a level statistically significant when the cross products clockspeed*flexibility and clockspeed*efficiency are introduced (ΔR^2 = .089 with F =13.12, significant at the 1% level). Conversely, introducing the other two cross products (clockspeed*rigidity and clockspeed*codification) has a negligible effect (ΔR^2 = .005 with F =.618). Hence, the degree of instability of an industry sector affects the probability benefiting from an ERP adoption only through its indirect impact on process flexibility and process effectiveness, but it does not influence the impact of the organizational variables.

It is also worth noting that, consistently with our initial conjectures, the direct impact of the degree of turbulence of the firm's operating environment is always negative (although with low levels of statistical significance): in high clockspeed industries it is systematically more difficult to achieve operational improvements after the adoption of an ERP system than in stable sectors characterized by a relatively low rate of turbulence.

Finally, several interesting findings emerge when one tries to interpret the sign of the moderating effect of clockspeed, which is quite surprising. On the one hand the coefficient of the cross product clockspeed*efficiency is positive, thus suggesting that in highly turbulent markets increasing the efficiency of processes is proportionally more advantageous than in stable environments[23]. On the other hand, and in sharp contrast with our initial expectations and with some of the most recent conceptualizations of the dynamic capability construct (Eisenhardt and Martin 2000) the moderating effect of clockspeed on process flexibility is *negative*. That is, the same increase of process flexibility observed after ERP adoption is proportionally more beneficial to the achievement of operational improvements for firms that operate in stable markets than for companies in highly turbulent sectors.

Needless to say, this result is surprising and deserves further discussion. A first plausible explanation would consider the fact that flexibility typically exhibits decreasing returns, that is, the fact that the advantages of increasing the flexibility of a process decrease with the initial degree of flexibility of that process (Jordan and Graves 1995). Based on this observation one would expect that the companies in our sample that obtained the lowest benefits form an ERP-driven increase of flexibility (i.e. companies in turbulent markets) would also display high degrees of flexibility before the ERP adoption. Unfortunately from our survey we did not have data on the pre-ERP degree of flexibility so as to test directly for this hypothesis. However, an indirect validation of this conjecture comes from the fact that, - as demonstrated empirically by (Mendelson and Pillai 1999), companies that operate in unstable do undertake process and organizational changes more frequently (i.e. they are intrinsically more flexible) than those that operate in stable markets.

A second interpretation considers the trade-off between exploration and exploitation (March 1991) and the extent to which the adoption of an ERP system is used to emphasize the first or the second behavior. Our measure of process flexibility appraises the degree to which a firm explores new process configurations (as opposed to the extent to which it settles on a particular pattern and exploits it indefinitely). Therefore, from an organizational learning perspective the paradox described above is tantamount to saying that the marginal benefit of conducting additional exploration decreases when the turbulence of the firm's operating environment increases. This is only apparently contradictory: driven by the high dynamism of their markets, firms

[23] This is consistent with a resource-based perspective. Turbulent environments require continuous adaptation, which is often achieved at the expenses of efficiency (i.e. optimal resource use). Accordingly, precisely because maintaining or improving process efficiency is more difficult in these environments (i.e. it is a scarcer and, hence, more valuable resource) those companies that manage to successfully do so are expected to experience higher benefits.

in high-clockspeed industries are likely to undertake frequent process and organizational changes even in the pre-ERP era, and often above the level that would be optimal (i.e. they conduct *excess exploration*). For these firms a further increase of exploration would be less advantageous – if not even dangerous. Hence, any ERP implementation that emphasizes reengineering rather than knowledge codification and process stabilization (i.e. if the software is *de facto* used to generate further exploration) is not likely to produce significant operational improvements. Conversely, if it is the knowledge codification aspect to be emphasized, the adoption of an ERP system is likely to generate larger and more visible benefits.

By the same token, firms in low-clockspeed sectors are often locked in a state of underexploration. Pushed by the natural stability of their operating environments they typically overemphasize the exploitation of existing processes at the expenses of exploring alternative and potentially superior configurations. Contrary to the previous scenario, for these organizations conducting additional exploration would be by far more beneficial than for high-clockspeed companies. Indeed, this objective can be achieved if the ERP implementation strategy appropriately emphasizes BPR and if the firm profits from this opportunity to maintain *some* level of exploration even after the live date.

Figure 7 ABOUT HERE

5.6.6 Sensitivity analysis

In order to verify the robustness of our results we re-estimated the models above using a different set of variables to operationalize each organizational and process-related construct. More precisely we measured the 3 process related variables (quality of information, efficiency and flexibility) and the two organizational constructs (rigidity and codification of procedures) by means of all the individual items factor-analized in paragraph 5.3[24]. The results - reported in Table 14 for some of the model analyzed - confirm the general conclusions drafted in the previous

[24] The new scales were constructed by taking the weighted average of the individual items that loaded on each specific factor, the weights being the factor loadings.

paragraphs, although both the models and the individual coefficients display a slightly lower level of significance.

	Model 3	Model 6	Model 8	Model 9	Model 10	Model 11
Intercept	4.09	1.84	1.71	1.77	1.29	1.29
	(9.08)***	(2.03)**	(1.89)**	(1.89)**	(1.26)**	(1.26)**
Project Execution	0.06	-0.02				
	(0.81)	(-0.35)				
Project Scope	0.44	0.29				
	(1.12)	(0.89)				
Project Duration	0.03	0.02	0.02	0.02	0.03	0.03
	(1.78)**	(2.08)**	(2.13)**	(2.09)**	(2.25)**	(2.25)**
Location	-0.16	-0.24				
	(-0.78)	(-1.39)				
Quality of Information		0.10	0.12	0.12	0.16	0.16
		(1.18)	(1.38)	(1.38)	(1.84)**	(1.84)*
Process Efficiency		0.30	0.28	0.27	0.04	0.04
		(4.85)***	(4.43)***	(4.22)**	(0.29)	(0.29)
Process Flexibility		0.08	0.10	0.11	0.40	0.40
		(1.53)*	(1.48)*	(1.49)*	(2.60)***	(2.60)**
Organizational rigidity			-0.07	-0.07	-0.07	-0.07
			(-1.45)*	(-1.46)*	(-1.10)	(-1.10)
Codification			0.08	0.08	0.08	0.08
			(1.27)	(1.53)*	(1.29)	(1.29)
Clockspeed				-0.04	0.16	0.16
				(-0.26)	(0.32)	(0.32)
Clockspeed x efficiency					-0.26	
					(-2.10)**	
Clockspeed x flexibility					0.18	
					(1.86)**	
Clockspeed x rigidity						-0.26
						(-2.10)
Clockspeed x codification						0.18
						(1.56)
DF						
R^2	0.09	0.38	0.40	0.40	0.44	0.40
Adj. R^2	0.03	0.34	0.34	0.33	0.36	0.31
F Value	0.40	9.65***	6.78***	5.73***	5.16***	4.46***
ΔR^2		0.31***	-	-	0.04**	-
Number of Observations	69	69	69	69	69	69

(t-statistics in parentheses: * = significant at 10%; * * = significant at 5%; *** = significant at 1%)

Table 14: OLS results for models with alternative variable measures

5.7 Conclusions and avenues for further research

This analysis represents a first step towards a deeper understanding of the phenomena through which the implementation of large and complex information systems affect the operational effectiveness of a business organization. The results summarized above reinforce our initial conjecture that referring to an IT productivity paradox "tout court" is not entirely appropriate. The impact exerted by IT systems - and by ERP systems in particular, on operational performance is not positive or negative "a priori". Rather, it is contingent on several firm-specific and market-specific variables.

By providing a tentative theoretical explanation for the large performance differences that have been typically observed across ERP adopters in many different industries the proposed model also supports our initial claim that the impact of an enterprise system extends far beyond the simple IS core of the firm. The results indicate that the information quality improvements consistently occurred in our sample of firms cannot explain by themselves the different changes in key performance indicators observed across adopters. Conversely, these changes are best explained by the modification of process efficiency and process flexibility that occurred as a result of ES implementation. These two properties clearly come forward as the true constituents of the dynamic capability construct at the operational level.

We have also highlighted that an ERP adoption does not occur in a vacuum. Rather, it takes place inside an established organization, with its codified behaviors, routines and rooted working habits. This host environment naturally interferes with the knowledge codification processes that accompany the ERP implementation, therefore amplifying or attenuating the system's impact on operational effectiveness. Two attributes suggest themselves as main drivers of this process, which display an antithetical effect. Whereas organizational rigidity has a negative impact on performance, the existence of codified organizational procedure even before the ERP adoption emerged as an enabler rather than a hurdle for the achievement of operational improvements. We suggest that this is due to the fact that in organizations where the reliance on formal procedures was a common practice already before the ES implementation the new system was perceived as a competence-enhancing innovation, thereby being more easily exploited to generate improved operational effectiveness.

Finally, market dynamism also influences the process observed, through its moderating effect on process flexibility and efficiency. However, and in contrast with our expectations and with the common conceptualization of the dynamic capability construct, process flexibility seems to be less valuable in turbulent markets than in stable industry sectors.

By shedding some light on the complex phenomena that link IT adoption, operational effectiveness and performance increases, and by distinguishing between structural (i.e. technology-dependent) and firm-dependent factors, these results may provide useful practical guidelines both to ERP adopters and software vendors.

This work is obviously only a preliminary step towards a better understanding of the major phenomena that determine the operational impact of complex IT projects and it naturally points out avenues for further research. At least two are worth being mentioned. First and foremost, it remains to be investigated whether and to what extent different configuration strategies (customization vs, standardization) and different managerial behaviors during the project implementation phase may affect the probability of generating operational improvements. Second, it has to be examined whether the observed changes of operational effectiveness produce effects of the financial bottom line of the ES adopters. The first question will be addressed in the following chapter.

Chapter 6

Knowledge integration and the development of IT capabilities: configurations of ERP adopters in the European and US manufacturing sector

6.1 Introduction

Both the academic and the business community manifest a renewed and increasing interest for knowledge, knowledge management and for learning processes. On one hand scholars increasingly recognize the importance of these activities for the generation of capabilities and for the achievement of competitive advantage. On the other hand, the widespread diffusion of knowledge management initiatives in many organizations and the parallel proliferation of consultancy firms that provide specialized services in this area are also symptomatic of the fact that this interest has overcome the boundaries of the academic world to embrace those of the business community at large. Faced to turbulent markets, blurred technological landscapes and fierce competition an increasing number of companies realize that developing and maintaining a solid knowledge repository is often a very viable strategy to hedge against uncertainties and market risks.

As a direct consequence of this new centrality, information systems also assume a new and more fundamental role. Not only do these systems accomplish a mere transactional function to support the execution of back office operations. They also become a key strategic tool that "provides cost-effective functionalities for building knowledge platforms through systematic acquisition, storage and dissemination of organizational knowledge [Purvis et al. 2001, p. 117]. As this is recognized as a primary strategic resource for organizations and a source of competitive advantage (Prahalad and Hamel, 1990), (Prahalad and Hamel, 1994), (Kogut and Zander, 1994) this function becomes of paramount importance, especially in dynamic markets where the manipulation of knowledge resources is particularly critical (Grant, 1996), (Kogut and Zander, 1995) and requires appropriate organizational architectures (Mendelson, 2000).

However, while companies invest significant amounts of resources to update and ameliorate their IT infrastructures, either by progressively introducing new components or by radically replacing different legacy systems with a single integrated solution, the returns of these investments both on productivity and profitability remain uncertain (Brynjolfsson, 1993; Hitt and Brynjolfsson, 1996a; Hitt and Brynjolfsson, 1996b; Upton and Mcafee, 1998) (Strassmann, 1990). Even at the organizational level there is an evident and significant gap between the adoption and the actual assimilation of complex information technologies (Purvis et al., 2001).

Both industry surveys and academic research provide ample evidence that the mere increase of a firm's IT expenditures does not guarantee – by itself, the achievement of performance improvements. It is only when it is accompanied by the development of effective IT *capabilities* that the adoption of an IT innovation produces operational improvements and – possibly, sustained competitive advantage (Bharadwaj, 2000;Markus and Benjamin, 1996). However, while the importance of developing these capabilities becomes increasingly more evident, it is still not clear how they can or should be generated.

The lack of specific knowledge in this area is important and deserves further investigation. In chapter 3 we have established that complex information systems exert a structural[25] impact on the operational antecedents of dynamic capabilities. However, we have also argued that this impact can be attenuated or amplified by means of appropriate implementation strategies. Consistently with this perspective, we suggest that to examine whether they are truly "appropriate", these strategies should be analyzed with respect to their influence on the knowledge integration mechanisms that subsume the generation of organizational capabilities.

There is indeed ample evidence that the design and the implementation of IT infrastructures affect the key mechanisms that underlie the development of these capabilities. These systems support the process through which a firm converts tacit knowledge into explicit knowledge, which is typically recognized as the most critical challenge for organizations (Nonaka and Takeuchi, 1995). By requiring a critical review of the existent practices and important cognitive efforts (Davenport and Short, 1990), an IT implementation facilitates the evolution of a firm's knowledge repository from the individual level (where it is mainly based on sense making), to the group level (where knowledge integration is the key priority) and to the organization level (where knowledge integration and institutionalization become prevalent) (Jiang et al., 2001).Also, throughout its entire development it activates the four mechanisms that are typically ascribed to support knowledge integration: the use of rules and directives to codify tacit knowledge into explicit instructions (Demsetz, 1991; Grant, 1996), the incorporation of refined knowledge into production

[25] I.e. independent of the particular implementation strategy chosen.

rules associated with work processes, the development of routines that facilitate the coordinated interventions of experts in the organization (Nelson, 1991) and, also the use of teams and meetings (Van de Ven et al., 1976).

However, while it is evident that IT implementations do affect the knowledge integration process behind the development of effective capabilities, it is less clear whether the different types of learning investments that can be undertaken during this activity are equally effective for the achievement of this objective.

Studies on knowledge and learning in general (i.e. not in relation to the development of IT capabilities) have contributed to refine our understanding of these phenomena and have shed light on the different cognitive mechanisms that contribute to the generation of different types of knowledge, both at the individual and at the organizational level. Yet, whereas it is clear that a variety of knowledge management strategies can be viable, and that in some contingent situations some are more effective than others (Inkpen and Dinur, 1998), no specific mechanism emerges as generally superior.

Particularly important for the phenomena we wish to examine are knowledge codification and articulation efforts (Zollo and Winter, 2001), which play a pivotal role in the implementation of complex IT systems. Yet, even in this case, it is still uncertain whether and in which circumstances these efforts contribute to develop effective capabilities, especially in turbulent markets. For instance, whereas it is argued that articulated and codified knowledge help firms address dynamic environments because it diffuses more rapidly and more efficiently (Nonaka and Takeuchi, 1995), it is also acknowledged that overcodified organizational routines produce core rigidities (Leonard-Barton, 1992) and become intrinsically hazardous. On the other hand, while it is typically recognized that simple rules, iterative (i.e. non-linear) processes, and experiential learning are the most appropriate capability-building mechanisms in high-velocity environments, it has been also suggested that low levels of process formalization may produce completely unstructured or "organic" capabilities, which are equally ineffective or dangerous (Eisenhardt and Martin, 2000).

The discussion above suggests that when using a knowledge-based perspective to analyze the development of IT capabilities several important questions still remain unanswered and deserve further investigation. In particular, what type of capability-building mechanisms and learning investments do companies privilege in relation to the implementation of complex information technologies that require knowledge integration efforts? Also, can any relationship be unveiled between the type of capability building mechanisms adopted and the environment (both external and internal) in which the firm operates? Do different mechanisms display different degrees of effectiveness, either in general or in relation to the operational environment and the organizational architecture of the firm?

The purpose of this chapter is to shed some light on the above questions. Following the renewed interest for organizational gestalts (Miller 87 and 90, Meyer et al. 1993, (Bensaou and Venkatraman, 1995; Atuahene-Gima and Ko, 2001) we adopt a configurational approach. Within this perspective, the above questions reduce themselves to a more general one, which consists in understanding whether IT adopters organize themselves according to "internally consistent combinations of strategy, organizational architecture and technology that provide superior performance in a given environment" (Tidd and Hull, 2002, p. 7) and whether these configurations display a different degree of effectiveness in different competitive settings.

Our underlying research hypothesis is that, as knowledge and learning investments are important determinants of operational effectiveness and as IT systems play a paramount role in enabling these activities, IT implementation strategies that entail knowledge development efforts should be also designed to spouse the specific requirements of the firm's operational environment.

Once again we decided to examine the research questions highlighted above by focusing on Enterprise Systems, for several important reasons. First and foremost, these technologies are the perfect archetype of a complex information system that requires intensive knowledge integration efforts. The four major phases that characterize their implementation -- IS planning, business analysis, system design and actual construction (Hackathorn and Karimi 1988, Martin 1990) -- are all knowledge intensive processes that "force" the adopter to choose among well determined configuration strategies, which are representative of the different knowledge investments we wish to examine. Second, whereas oversimplified bullet-proof implementation models are often proposed by IT consultants, it is evident that a large number of enterprise projects still do not match expectations and that there is no easy and generally applicable way to guarantee the development of effective IT capabilities in this domain. In turn, this suggest that there is an urgent need for sounder and theory-driven implementation models that – after taking into account the specific idiosyncrasies of the adopter, help firms maximizing the benefits of their ERP investments. Third, the magnitude of the investments associated with these systems renders the cost of a potential failure almost prohibitive and reinforces the urge to deepen our understanding of these phenomena. Finally, the very large diffusion that enterprise systems have experienced in the last few years facilitates the collection of reliable data and it is a guarantee for the robustness of this research.

The remainder of this chapter is organized as follows. In section 2 we develop a conceptual model of fit between ERP needs and ERP capabilities, which is based on the fundamental premise that an ERP implementation must match the characteristics of the adopter's operational environment. In section 3 we describe the analytical approach that we used to uncover configurations of ERP adopters in a sample of European and US firms that have implemented SAP R/3. In section 4 and 5 we assess respectively the descriptive and the predictive validity of the proposed taxonomy. Finally in section 6 we conclude and discuss avenues for further research.

6.2 A conceptual model of fit between ERP needs and ERP capabilities

To address the research questions discussed above we develop a configurational analysis following a deductive and theory-driven approach (Ketchen and Shook, 1996). To this end we develop a stylized conceptual model that considers the capabilities developed by the adopters of complex information systems throughout the software implementation process vis à vis the characteristics of the external environment where the firms operate. The model extends the one proposed by (Bensaou and Venkatraman, 1995) and it is anchored to a main theoretical perspective.

The general theoretical foundation of our analysis is the widely accepted view that - for purposes of effectiveness, firms should generate capabilities or deploy resources in accordance to the requirements of the environment in which they operate. This theoretical perspective enjoys a long history in management literature (Lawrence and Lorsch, 1967;Thompson, 1967) and it has taken different conceptualizations in the various disciplines that it has -- directly or indirectly --

influenced: in economics with the notion of complementarity (Milgrom et al., 1991; Milgrom and Roberts, 1990), in organization theory with the distinction between mechanistic and organic structures (Burns and Stalker, 1961) or in operation management, where both production systems (Keller et al., 1974) and supply chains (Fisher, 1997) have been analyzed in relation to different environmental contingencies.

However, whilst researchers have often used this paradigm to study "ex-post" the type of capabilities that best fit specific environments, they have seldom applied it to examine the mechanisms through which these capabilities are generated. Also - with the noteworthy exception of (Bensaou and Venkatraman, 1995) which has adopted the environment-fit perspective to study information systems with respect to their ability to support buyers-suppliers relationships in the automobile sector, scholars have rarely used this paradigm to examine technology innovation processes. Needless to say, these are important caveats, especially for those technologies, whose adoption affects the internal resource allocation process of a firm and the functioning of its business processes. If effective capabilities must match environmental needs, and if the adoption of a complex IT system determines the nature of these capabilities, it then follows that both the choice of the technology and its implementation should be adapted to the environment in which the adopter operates.

When analyzed through the information-processing view of the firm, (Cyert and March, 1963; March and Simon, 1958; Tushman and Nadler, 1978), the "structure-environment" perspective takes the simple and elegant formulation proposed by (Daft and Lengel R.H., 1986). Organizations are seen as networks of information processors who assimilate information from the external environment, match it with knowledge accumulated internally and act on it by means of their capabilities, which - to be effective, must fit the specific information processing needs of the firm. For instance, in highly turbulent markets organizations are required to respond effectively to rapid change and "must be aware of the new information generated in its environment and adopt structures that enable fast decision making, using information which is available on the spot, systems that facilitate its dissemination and practices that reduce information overload" (Mendelson, 2000), p. 515).

This formulation is also the point of departure of our analysis. In the following we extend the original Daft and Lengel's framework into a more comprehensive model, which takes into account both the equipment (i.e. IT) and the organizational nature of the technology (Corbett, 1992). The central tenet of our approach is that in the case of complex information systems whose role goes beyond that of a pure transactional instrument it is not sufficient to limit the assessment of needs to the mere information-processing domain. Besides performing a basic *information processing function* (i.e. ensuring a timely, accurate and consistent flow of information and data across the different layers of the organization) these technologies also ensure a *process integration and an organizational function.* They support business processes by helping the firm integrate and streamline its operations and standardize them across its many different units. They are also often used as a change agent to prompt process and organizational transformation that would be otherwise difficult to accomplish.[26] Indeed, the latter function is often cited as the most important characteristic and the true challenge for next generation of information technologies (Markus and Benjamin, 1996).

Accordingly, when filtered through this lens, the environment-fit perspective suggests that successful ERP adopters should develop capabilities that adequately match simultaneously their information processing needs and, also, their process integration and organizational needs (Figure 8). This multi-facet perspective on needs and capabilities is also consistent with research that has identified external environmental characteristics and organizational features as the main contingencies that influence the effectiveness of different knowledge intensive capability-building mechanisms (Zollo and Winter, 2001) and with studies that have examined the contingencies that influence the relationship between organizational complexity and innovation (Damanpour, 1996). As capabilities are generated by means of deliberate instruments (knowledge integration and learning investments), the contingency argument we advocate suggests that these instruments should also be adequately matched to the idiosyncratic requirements of the firm's internal and external operational environment. Differences in "fit" between the needs and the capability-generating mechanisms -- more than the choice of a particular configuration strategy "per se"-- should possibly explain the differences in operational performances observed across adopters.

[26] Indeed, as noted by the executive of a large manufacturing firm, "this second function is often the primary one. One of the main reasons why most companies undertake such a long and painful endeavor is often the need to implement organizational changes, which would be impossible to realize without the pretext of an ERP implementation".

Figure 8 ABOUT HERE

6.2.1 ERP needs

6.2.1.1 Information processing needs

Consistently with the information processing view of the organization we recognize that information processing requirements arise from the fact that firms must cope with various forms of uncertainty (Galbraith, 1973; Tushman and Nadler, 1978).

We distinguish two general sources of uncertainty. The first type – which is observed at a "macro" level and it is a function of the intrinsic dynamism of today's markets - is related to the amplitude of the possible "shocks" to which the firm must promptly react. Confronted to constantly changing customer requirements, unpredictable demand, short product life cycles, and to ever accelerating rates of technological change, companies need efficient transactional instruments to handle and update in a timely fashion a very large amount of information and data about products, processes, and business partners.

We account for this form of uncertainty be means of two constructs. The first – "environmental dynamism" - measures the overall degree of turbulence of the firms' operational environment and it is akin to Fine's notion of clockspeed (Fine, 1998). The second – "internal process dynamism", is akin to the notion of task uncertainty (Hunt, 1970; Perrow, 1967) and it assesses the degree of uncertainty that intrinsically occurs inside the firm's boundaries as a result of the particular production system implemented. Greater uncertainty is associated with the manufacturing of customized products (which are subject to frequent changes in the design specifications) and with a made-to-order production system, which causes production plans and delivery schedules to be often revised to spouse customers' requirements (Keller et al., 1974).

The second general form of uncertainty is strictly connected to the notion of complexity (Duncan, 1972) and it arises from the "heterogeneity and range of an organization's activities" (Child, 1972) (i.e. from the number of executable tasks) that require the information system's support. As this type of complexity typically increases more than proportionally with the number of tasks and with their variety and as both are also a function of product variety, we consider the "number of product categories" as an effective proxy for this construct.

6.2.1.2 Process integration needs

In sharp contrast with simpler information technologies, whose main functions remain confined within the mere information-processing domain, ERP systems respond to a broad range of operational requirements that embrace process integration aspects. Process integration needs originate from the fact that enterprise systems can help an organization streamline processes across different units, and redefine the execution of tasks, the allocation of roles and responsibilities and – especially, the level of access to information that is granted to different members. As such, not only do they provide the backbone for information processing, but they are also changing in fundamental ways how organizations operate (Child, 1987; Davenport and Short, 1990; Hammer, 1990).

We consider specifically two types of process support needs. The first one originates from the degree of "environmental heterogeneity" of the firm, which creates the need to find the right balance between the development of specialized capabilities versus centralized competences (Allen and Boynton, 1991), particularly in the case of multi-site organizations whose IT infrastructure need to support a large number of business processes in different sites. In accordance to the "principle of requisite complexity" (Ghoshal and Nohria, 1990) the degree of similarity or dissimilarity across sites determines the optimal amount of process standardization that a firm should achieve. Since "under norms of administrative rationality a firm should match its internal organizational complexity with its environmental complexity" (Thompson, 1967) we expect that greater environmental homogeneity (i.e. a greater similarity across different sites) should produce a greater pressure to integrate and standardize business processes. In turn, as process standardization is indeed one of the principal drivers that motivate ERP adoption, and as the degree of ex-post process standardization is determined also by the implementation strategy chosen, we also expect the degree of ex-ante internal heterogeneity to have a profound influence of the type of ERP capabilities (integrative vs. localized) that a firm decides to develop.

The second type of process needs - "supply chain function", considers IT systems specifically in relation to their role in supporting the processes dedicated to the delivery of products and services to the market. Since ERP are often implemented to streamline and upgrade supply chains (Rachna, 2002), SCM has to be addressed explicitly. The variable accounts for the fact that different competitive priorities at the supply chain level may generate very different needs on the information systems infrastructure that support them, which have to be designed accordingly. A supply chain exerts simultaneously two distinct functions – a market mediation function and a physical function (Fisher, 1997; Taylor, 2001), which also entail very different costs. Accordingly, different competitive priorities and the different types of products distributed may induce the firm to privilege one particular aspect versus the other. Efficient supply chains – which are designed to privilege the physical function, emphasize cost reduction, even if this choice may entail low levels of customer service (i.e. a poor performance along the market mediation dimension). Conversely, responsive chains privilege the market mediation function (i.e. the ability to exactly meet demand) even if achieving this goal may entail additional costs and render the system inefficient. Obviously, privileging efficiency versus flexibility entails very different needs for the IT infrastructure that supports supply chain processes (Allen and Boynton, 1991).

6.2.1.3 Organizational needs

Organizational features and organizational culture have often been identified as critical determinants for the success of IS projects and – especially as elements that should be accounted for when designing and implementing new IT systems (Mohan et al., 1990). In line with this view, the third general mechanism that determines the ERP needs that we consider is related to the organizational nature of the technology and, in particular, to its role as an instrument to initiate organizational innovation processes. This function becomes increasingly important as both the academic and the business communities recognize that IS and IS specialists need to become better agents of organizational change (Markus and Benjamin, 1996). By redefining roles and responsibilities and by structuring the level of access to information and data inside the organization, enterprise systems provide the adopter with the opportunity to redefine in a very specific fashion its organizational architecture. As such, the adoption of these technologies becomes *de facto* a process of organizational turnaround that has to be conceived, designed and managed with extreme care.

Organizational requirements stem therefore from the need to design and implement IT infrastructure in a way that fits the organizational attributes of the organization, with respect to the degree of task formalization (Goodhue and Thompson, 1995), to the level of access to information and data that is granted to different users and, especially, with respect to the different cognitive styles that have become predominant in the organization (Benbasat and Taylor, 1978).

Organization theorists have traditionally distinguished between mechanistic and organic structures (Burns and Stalker, 1961), enabling and coercive bureaucracies (Adler, 1999; Adler and Borys, 1996), or more recently – between industrial age and information age organizational architectures (Mendelson, 2000). The two different categories of archetypes respond to very different needs of the firm. "Industrial age" or mechanistic structures are primarily designed to optimize the use of limited physical resources and privilege rigid hierarchies, compartmentalized execution of operations and a strict control of information. Conversely, "information age" or organic organizational architectures "support decision making in fast-moving, information-rich environments, where information management and knowledge assimilation are crucial activities" [ibid. p. 515]. They are based upon a more agile formalization and are best suited for companies that operate in high clockspeed industries.

In line with the fit perspective advocated above, we suggest that the two stylized archetypes also demand a different type of IT support, which privileges either information transfer "agility" or a more rigid structuration of organizational layers and a consequent differentiated access to information inside the firm.

To assess the organizational needs of the firm along the mechanistic-organic continuum, we consider the "degree of organizational rigidity", i.e. the extent to which the organization functions in accordance to formal and rigidly defined procedures (Staw et al., 1981). Accordingly we expect agile organizations that display informal bureaucracies to exhibit different ERP needs than mechanistic organizations, where command and control type of formalisms are privileged over agility.

6.2.2 ERP capabilities

The central tenet of our approach is that - as complex information systems respond to needs that transcend the mere information-processing domain, the capabilities that firms generate to respond to these requirements must also embrace broader competences that go beyond the pure IT core. In particular, for IT innovations that affect the IS, administrative and technical core of a company (Grover et al., 1997; Swanson, 1994), they need to involve operational (i.e. related to business processes) and organizational aspects (i.e. related to the computer-human interface)[27].

Within the environment-structure framework, researchers have started applying a contingency perspective to investigate the relation between capabilities and environment, with the objective to examine whether specific competences display a different degree of effectiveness when applied to different competitive settings. However – with few noteworthy exceptions (Zollo and Winter, 2001), they have generally attempted to study the type of capabilities that best fit specific environments only after the former are consolidated and structured. Conversely, they have rarely investigated upon the mechanisms through which these capabilities are generated, maintained and possibly improved.

Rather than to compare ex-post the characteristics of the ERP capabilities to the environmental needs of the adopters, in the following we examine the different types of *mechanisms* that the firm possesses to generate these capabilities and we analyze their effectiveness in relation to its operational environment.

Mindful of the increasing importance that knowledge and learning assume in modern organizations (Spender, 1996), and of the fact that IT implementations are de facto processes of collective learning through which the firm improves the understanding of its business processes and share cognitive models (Boland et al., 1994), we couch this analysis in the domain of knowledge and knowledge management .

[27] This perspective was also validated empirically by the many interviews that we conducted with business managers involved in, or affected by, an ERP implementation. Indeed, the large majority of interviewed stressed that most of the problems arising during and especially after the software implementation were not technical but rather organizational or operational, and that "soft" ERP capabilities were considerably more important than "hard" ones.

We identify three fundamental "process" mechanisms, through which an organization can affect the development of its IT capabilities during the development of an IS project. The first mechanism determines the nature of the knowledge developed. The second mechanism considers its sourcing process, and in particular whether specific competences are developed in house as opposed to being outsourced. The third mechanism involves the process through which knowledge and competences embedded in the new business processes are finally diffused and integrated in the organization.

6.2.2.1 Knowledge development

We consider three specific facets of the knowledge generation mechanism that occurs during the implementation of an ERP system. The first and most important is the "degree of knowledge articulation" (Zollo and Winter, 2001). Akin to the notion of conceptual learning (Mukherjee et al., 1998), this construct measures the extent to which the firm spends time and resources to develop a deeper understanding of the phenomena that determine the effectiveness of its business processes. Knowledge articulation efforts facilitate the process through which knowledge "owned" at the individual level is shared and becomes collective (Okhuysen and Eisenhardt, 2002), they also reduce causal ambiguity (Lippman and Rumelt, 1982) and help the firm develop a greater understanding of the cause-effect relationships that ultimately determine the effectiveness of its operations. In ERP implementation processes, knowledge articulation efforts are typically undertaken with different degrees of intensity during the phase of "gap analysis" that typically precedes or accompanies the design of the new business processes[28].

The second aspect that we consider, the "degree of IT focus" accounts for the "type" of knowledge that the firm chooses to develop and it is idiosyncratic to complex IT systems that have an organizational impact. Both the academic and the

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[28] Researchers often distinguish between processes of knowledge articulation and knowledge codification, where the second construct refers to the generation of formal models, procedures and organizational routines that render explicit and widely accessible the tacit competences embedded in the organization. In any ERP implementation the codification process occurs by default because of the adoption of the business process templates included in the software. Conversely knowledge articulation may largely vary depending on the amount of resources that the adopter is willing to dedicate to the phase of gap analysis that should precede the configuration.

business community increasingly recognize the importance and the difficulty of developing multidimensional IT capabilities, which bring together both "pure" IT skills and business and organizational competences (Lee et al., 1995). ERP projects are typically positioned between two opposite extremes, with the first model being the one most often represented. At one end "pure IT" projects emphasize the development of IT competences. In this case most of the time and the resources available are allocated to the solution of technical aspects (configuration of hardware and software, organization of data bases, elimination of inconsistencies across different legacy systems, etc.). At the other extreme "organizational projects" use the software adoption mainly as a means to trigger organizational changes and to streamline operations. In this second case the resources allocated to the phase of process analysis that precedes and accompanies the software configuration per se may exceed those spent to deal with pure technical aspects.

The third aspect - the "degree of project customization", reflects the fact that the successful use of a new technology requires the mutual adaptation of the technology and the organizational context into which the technology is being introduced (Leonard-Barton, 1988). To account for this effect we consider the extent to which the adopter decides to customize the software as opposed to implementing a standardized template.

6.2.2.2 Knowledge sourcing

The second general IT capability-building mechanism is related to the source of competence used to develop process and IT knowledge and it reflects a fundamental degree of freedom in an ERP configuration strategy: the extent to which the adopter relies on external consultants to manage and execute the implementation of the software (as opposed to managing the process in-house with its own resources).

The risks and benefits of outsourcing knowledge development activities have been extensively analyzed, both in general and in relation to IT projects (Wang et al., 1997; Ang and Cummings, 1997; McFarlan and Nolan, 1995). There is a fundamental trade-off associated with these alternative strategies. Whilst developing capabilities in-house facilitates learning-by-doing and fosters the generation of process knowledge, it also demands greater efforts and it may penalize firms that do not possess advanced capabilities in this domain. Conversely, a radical outsourcing strategy provides access to specialized IT capabilities and reduces the risk of implementation failures, but it also hampers the development of in-house competences, which might prove dangerous in the long run.

This aspect is of particular importance for ERP projects, because consulting expenditures may represent a very large part of the overall project cost[29] and, hence, significantly constrain the choices operated during the implementation. To take into account its different aspects, we assess the degree of project outsourcing by means of four different measures, namely:

- The percentage of total project costs which are due to consulting expenditures;
- The proportion of consultants in the project development team;
- The degree to which the phases of business process reengineering and gap analysis are operated by external consultants as opposed to internal members of the host organization
- The degree to which pure technical tasks are executed by external consultants as opposed to internal members of the host organization

It is appropriate to distinguish between consulting cost and the proportion of consultants in the project team, as the two indicators are not necessarily correlated. As a SAP manager pointed out, ERP adopters are typically assisted by two different types of consultants, who also entail very different costs. General strategy consultants often assist the company throughout the BPR phase that precedes the actual implementation, but they are rarely involved in the software configuration per se. Conversely, pure IT experts typically limit their intervention to help the adopter configure the software and execute technical tasks. Hence, since the former category generally involves higher costs than the latter, a comparative assessment of both indicators provides also information on the type of implementation strategy adopted. High consulting expenditures accompanied by a limited number of consultants in the team are often an indicator of a strategy focused primarily on BPR. Conversely, low to medium consulting costs accompanied by a significant number of external experts in the implementation team is often a synonym of a low cost project, where the main goal is assuring the mere technical efficiency of the system adopted.

[29] Some companies surveyed for this research reported consulting expenditures as high as 75% of the overall project cost.

6.2.2.3 Knowledge dissemination

We have argued that an ERP implementation responds to an "organizational need" as it induces "changes in individual work patterns, management control and organizational structure" (Olson, 1982 p.71). The long configuration process and the gap analysis that characterize any ERP implementation are *de facto* a process of organizational design, in which the architecture of the company is reconfigured through a redefinition of the tasks to execute, a formalization of the underlying procedures and a reallocation of the responsibilities among employees. Furthermore, the system roll-out is also a process of knowledge dissemination, in which the new organizational routines developed during the phase of software configuration and codified in the software templates are finally made available to a large number of end-users and contribute to the distribution of cognitive models within the organization (Boland et al., 1994).

In line with the environment-structure perspective, we argue that the type of formalization that results from this organizational turnaround and from the dissemination of the cognitive models embedded in the best practices must also match the characteristics of the environment in which the adopter operates. However the type of formalization that characterizes the organizational routines in the post-adoption epoch is not uniquely dependent on the structural characteristics of the system implemented. To a great extent it is a function of how the implementation process is managed. Although typically regarded as rigid technologies, even complex information systems display some degree of "soft determinism" (Corbett 1992), and they can be "adjusted" to spouse the requirements of the adopter.

We suggest that the degree of fairness of the implementation process is the principal factor that differentiates among different strategies and that ultimately affects the type of formalization generated. A fair implementation process sees the close collaboration between the external consultants (who bring the technical expertise) and a pool of key end-users who bring the business expertise and become responsible for further transferring the ERP knowledge in the organization. The configuration also occurs incrementally, following a prototyping strategy aimed at achieving the optimal balance between technical efficiency, usability and conformity to the end user requirements. In this environment, regardless of the degree of task formalization typically required by the enterprise system, the new set of procedures is perceived as a useful guidance system to explore new forms of process design rather than a rigid constraint that stifles innovation and de-skills employees. By inducing voluntary cooperation (Kim and Mauborgne 1998) - both among employees and between consultants and employees - a fair process accelerates the generation of conceptual and operational knowledge (Bohn 1988; Lapré, et al. 2000). This view is also consistent with research that has highlighted the organizational significance of information ownership (Brynjolfsson, 1994) and the importance of knowledge sharing and trust (Nelson and Cooprider, 1996) and of employee involvement and influence (Robey and Farrow, 1982) as important drivers of IS performance.

We account for this construct by measuring two of the fundamental constituencies of a fair process, namely: engagement and explanation (Kim and Mauborgne 1995; Kim and Mauborgne 1996). Explanation measures the extent to which end users not directly involved in the software configuration process received clear and detailed explanations about the ongoing change, its reasons, characteristics and – especially, the expected consequences for their activities. Engagement accounts for the extent to which end users participated in the design of the new procedures, by being given the opportunity to provide feedback to the implementation team and, also, to actually influence the process.

In the following we use the conceptual model described above as an underlying framework to guide our investigation. By using it in conjunction with cluster analysis we seek to examine whether any coherent structure emerges in a sample of European and US manufacturing firms that adopted SAP R/3 in the past decade.

6.3 Methodology and analytical issues

6.3.1 Overall analytical approach

The main objective of our analytical approach is threefold, namely: i) to observe whether - grounded on the conceptual model sketched above, some archetypical configurations of ERP adopters emerge from the sample; ii) to assess whether the differences among configurations are significant; iii) to examine whether the different cluster memberships contribute to justify observed performance differences across firms. Mindful of the potential limitations that often accompany the use of a configurational approach in management research, we paid special attention to the methodological aspects of our study. Consistently with (Bensaou and Venkatraman,

1995) we applied the six-step approach summarized in Table 15 to unveil the different configuration of ERP adopters and to test for the predictive validity of the proposed taxonomy.

Step	Description
1	Development of the conceptual model of ERP implementation
2	Operationalization and measurement of constructs
3	Application of cluster analysis to identify configurations reflecting ERP needs
4	Application of cluster analysis to identify configurations reflecting ERP capabilities
5	Assessment of descriptive validity
6	Assessment of predictive validity

Table 15: Analytical approach

As first steps (1-2) we used the conceptual model of ERP implementation described in the previous paragraph to operationalize the 15 variables suitable for cluster analysis. It is worth recalling that this choice corresponds to adopting a deductive (or theory-driven) approach to cluster analysis as opposed to an inductive or exploratory one (Ketchen and Shook, 1996).

In steps 3 and 4 we followed the multi-tiered approach suggested by (Hambrick, 1983) to derive the configurations of fit between the ERP needs and the ERP capabilities. The first substep of this multi-tiered approach consisted in applying the clustering procedure to the entire sample using as discriminating variables only the constructs that define ERP needs. Obviously, the goal of this exercise was to identify groups of companies that - either because of the environments in which they operate or because of their internal characteristics, display similar requirements vis à vis an ERP implementation. As a second substep we used the 9 variables that define ERP capabilities to perform a second cluster analysis and we repeated the analysis for each of the different clusters that emerged from the previous step. The objective in this case was to identify companies that develop similar ERP capabilities, *within* each specific subgroup with homogeneous needs. Hence, the application of the two substeps identified clusters of companies (i.e. configurations) that have *both* similar ERP needs and similar ERP capabilities to respond to these needs.

In step 5 we assessed the descriptive validity of the configurations that emerged from the analysis. This was achieved first by verifying whether the proposed clustering had any statistical discriminating power and then by analyzing the peculiar characteristics of each cluster with respect to the variables that contribute the most to distinguish the clusters. Finally, in step 6 we examined the predictive validity of the proposed configurations by checking whether the clustering structure uncovered by the above analysis could explain the performance differences across ERP adopters.

6.3.2 Operationalization of variables and data collection

In line with the above approach, we dedicated particular care to operationalize the 15 explanatory variables in the conceptual model illustrated in Figure 8 (6 variables to describe the ERP needs and 9 to characterize the ERP capabilities). To increase the reliability of the measures, for each construct in the model we either used measures already validated by other research studies or – whenever possible, we constructed dedicated scales with a reliability coefficient above .70 (Nunnally, 1994). For each variable retained in the study, Table 16 summarizes the individual items used to form the scales and - when applicable, the reliability coefficient.

VARIABLE	N. items (alpha)	ITEM
OPERAT. ENVIRONMENT		
Environmental dynamism	3 (.74)	Length of product life cycle; Number of new products in the previous 5 years; Proportion of annual revenue from new products
Environmental complexity	2 (.73)	Proportion of customized products Proportion of products made-to-order
Environmental heterogeneity	3 (.72)	Proportion of sites located in the same country Prop. of sites that produce/distribute same products Proportion of sites that use same distribution channels
Product variety	1 (n.a.)	N. of product categories
Supply chain function	1 (n.a)	Extent to which SC priority is to reduce distribution costs vs. shorten lead times
Organizational rigidity	2 (.76)	Company has structured hierarchy with clear roles Salaries are dependent on formal position

Table 16: Operational measures of ERP needs and IT capability-generating mechanisms

VARIABLE	N. items (alpha)	ITEM
ERP IMPLEMENTATION		
Consulting expenditures	1 (n.a.)	*Proportion of total project cost ascribed to consulting*
Team composition	1 (n.a.)	Proportion of external consultants in project team
Consultant's role in IT	1 (n.a.)	Proportion of IT tasks delegated to consultants
Consultant's role in BPR	1 (n.a.)	Proportion of BPR tasks delegated to consultants
Explanation	3 (.82)	Extent to which end users were: (i) informed of changes produced by the software; (ii) informed of importance and goal of the project; (iii) informed before actual start
Engagement	2 (.78)	Extent to which: (i) end users were encouraged to criticize mgt decisions (ii) suggestions from end-users actually implemented
Software customization	3 (.70)	Extent to which (i) ERP was unable to support special processes; (ii) Software was adapted to processes (iii) New processes chosen outside ERP templates;
Focus	1 (n.a.)	Proportion of resources dedicated to technical tasks vs. BPR activities
Knowledge articulation	2 (.70)	Importance given to process analysis activities N. of process templates examined before fixing design

Table 16 – cont'd: Operational measures of ERP needs and IT capability-generating mechanisms

The data necessary to perform the analysis were directly gathered by administering a questionnaire to a randomly selected sample of companies that adopted SAP R/3 between 1996 and 2001, according to the procedure described in chapter 4. After eliminating questionnaires with missing values the sample contained 75 usable answers.

Table 17 reports the main descriptive statistics for the variables entered in the model, whereas Table 18 displays correlation coefficients.

	N	Mean	Std Dev	Sum	Minimum	Maximum
Environmental dynamism	75	3.16	1.44	237.20	0.00	5.36
Environmental complexity	75	9.24	3.62	693.30	2.00	14.00
Environmental heterogeneity	75	3.13	1.55	234.74	0.00	5.68
Internal dynamism	75	3.82	1.92	286.60	1.00	7.00
Supply chain function	75	3.68	1.63	276.07	1.00	7.00
Organizational rigidity	75	2.97	0.75	222.80	0.00	3.89
Knowledge articulation	75	9.54	2.81	715.55	2.00	14.00
Software customization	75	11.74	3.41	880.48	5.00	18.00
Consulting expenditures	75	0.44	0.20	32.78	0.05	0.75
Team composition	75	0.32	0.15	24.16	0.05	0.70
Role of consultants in IT activities	75	3.55	1.54	266.61	1.00	7.00
Role of consultants in BPR activities	75	11.91	4.06	892.90	4.00	21.00
IT focus	75	0.43	0.18	32.27	0.10	0.80
Explanation	75	4.82	0.81	361.39	2.89	5.84
Involvement	75	3.21	0.58	241.01	0.69	3.89

Table 17: Summary statistics

	Pearson Correlation Coefficients, N = 75														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Environmental dynamism															
Environmental complexity	0.268														
	(0.020)														
Environmental heterogeneity	0.188	0.226													
	(0.107)	(0.051)													
Internal dynamism	0.232	-0.228	0.150												
	(0.045)	(0.050)	(0.200)												
Supply chain function	0.110	-0.293	0.026	0.055											
	(0.347)	(0.011)	(0.823)	(0.638)											
Organizational rigidity	-0.223	-0.057	-0.244	-0.212	-0.045										
	(0.054)	(0.629)	(0.035)	(0.068)	(0.700)										
Knowledge articulation	0.083	-0.017	-0.258	-0.015	0.053	0.114									
	(0.477)	(0.882)	(0.026)	(0.899)	(0.651)	(0.332)									
Software customization	0.096	0.117	0.113	-0.029	0.074	-0.206	-0.262								
	(0.413)	(0.319)	(0.335)	(0.807)	(0.530)	(0.076)	(0.023)								

	Pearson Correlation Coefficients, N = 75														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Consulting expenditures	-0.107	-0.038	0.132	-0.042	0.046	0.112	-0.191	-0.089							
	(0.360)	(0.746)	(0.259)	(0.721)	(0.695)	(0.339)	(0.101)	(0.447)							
Team composition	-0.027	-0.007	-0.001	-0.207	0.018	0.165	0.069	0.056	0.437						
	(0.816)	(0.951)	(0.996)	(0.075)	(0.878)	(0.156)	(0.554)	(0.632)	(<.001)						
Role of consultants in IT	-0.051	0.075	0.208	-0.169	-0.046	-0.022	-0.175	0.244	0.170	0.416					
	(0.664)	(0.524)	(0.074)	(0.147)	(0.694)	(0.852)	(0.133)	(0.035)	(0.144)	(0.000)					
Role of consultants in BPR	0.006	-0.105	-0.112	-0.261	0.113	0.049	0.014	-0.002	0.414	0.552	0.289				
	(0.958)	(0.371)	(0.339)	(0.024)	(0.333)	(0.675)	(0.905)	(0.989)	(0.000)	(<.001)	(0.012)				
IT focus	-0.099	0.058	-0.059	0.120	0.000	0.105	-0.100	0.241	0.012	-0.015	-0.001	-0.105			
	(0.400)	(0.623)	(0.612)	(0.304)	(0.999)	(0.371)	(0.392)	(0.037)	(0.920)	(0.901)	(0.996)	(0.371)			
Explanation	0.071	0.058	-0.353	-0.070	0.103	-0.048	0.375	-0.270	-0.089	-0.002	-0.191	-0.028	-0.188		
	(0.547)	(0.618)	(0.002)	(0.553)	(0.381)	(0.683)	(0.001)	(0.019)	(0.448)	(0.986)	(0.101)	(0.809)	(0.107)		
Involvement	0.269	0.155	-0.152	-0.068	0.107	0.092	0.210	-0.121	0.109	0.252	0.101	0.015	-0.082)	0.249	
	(0.020)	(0.184)	(0.194)	(0.563)	(0.359)	(0.430)	(0.070)	(0.299)	(0.354)	(0.030)	(0.388)	(0.901)	(0.484)	(0.031)	

Table 18: Pearson s correlation coefficients

6.3.3 Clustering algorithm and selection of optimal number of clusters

To further reinforce the methodological robustness of our analysis we followed the set of recommendations suggested by (Punj and Stewart, 1983) and (Ketchen and Shook, 1996) to conduct cluster analysis. In particular, we used standardized variables to limit the spurious influence of the different scales used to measure the constructs[30], we retained Euclidean distances as similarity measures among groups and we applied Ward's method as agglomerative algorithm to form clusters.

More specifically, the following considerations also motivated our analytical choices. The use of Euclidean distance was appropriate because the low level of collinearity among variables did not necessitate the adoption of alternative as similarity measure such as the Malanhobius distance). The Ward's algorithm was preferred to other agglomerative techniques (such as the single, complete or average linkage methods and the centroid methods) because – besides its robustness – it offers the advantage to form clusters of the same size. The latter was a desired property given the relatively small size of our sample. Finally, the use of a hierarchical method to form clusters was preferred to non-hierarchical ones, because no theoretical reasons could justify the selection of an a priori number of clusters and because the relatively limited size of our sample did not pose any computational efficiency concern[31].However, a potential limitation of the latter choice is that, when hierarchical procedures (such as Ward's method) are used to form groups the selection of the optimal number of clusters is usually left to the researcher judgment. Needless to say this is one of the most often cited difficulties with the use of cluster analysis as a research methodology. To overcome this weakness and select *objectively* the optimal number of clusters we adopted the Variance Ration Criterion (VRC) proposed by (Calinski and Harabasz, 1974). The method was validated by (Milligan, 1981) through a series of Monte Carlo experiments that compared 30 different

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[30] For instance, whereas the role of consultants was measured by assessing the proportion of external consultants in a typical implementation team or the proportion of total costs due to consulting fees (hence through percentages), other constructs were assessed through 1-7 likert scales.

[31] For particularly large samples non-hierarchical techniques may be preferable as they minimize the computational time.

stopping rules over 4 different clustering methods (including Ward's method), and it has been extensively applied in management research.

Intuitively, for each possible number of clusters the procedure computes an index to weigh the marginal changes that occur in the "between clusters sum of squares" when a new cluster is added, against those that occur in the "within clusters sum of squares". More formally, the VRC index method identifies the optimal number of clusters k* in a data set as the one for which the following VRC function achieves a global or a first local maximum:

$$VRC = \frac{BGSS/(k-1)}{WGSS/(n-k)}$$

where:

n= total number of observations

k = number of clusters

$WGSS$ = (total) within groups sum of squares

$BGSS$ = between groups sum of squares

The values of *WGSS*, *WGSSi* and *BGSS* can be easily computed by considering what follows:

a) the total within-group sum of squares can be evaluated through one of the following methods:

$$WGSS = \sum_{i=1}^{k} WGSS_i \quad \text{or}$$

$$WGSS = \frac{1}{2}((n_1 - 1)d_1^{\,2} + (n_2 - 1)d_2^{\,2} + ... + (n_k - 1)d_k^{\,2})$$

where d_g^2 is the general mean of the $n_g(n_g - 1)/2$ squared distances d_{ij}^2 among data points and d_{ij}^2 is the generic distance between two data points P_i and P_j:

$$d_g^{\,2} = \frac{\sum_{i=1}^{n_g}\sum_{j=1}^{n_g} d_{ij}^{\,2}}{n_g(n_g-1)/2}$$

$$d_{ij}^{\,2} = (x_i - x_j)'(x_i - x_j) \quad with\, i,j = 1,2,\ldots n.$$

b) the total between-groups sum of squares is given by $BGSS = TSS - WGSS$, where the total sum of squares TTS can be also obtained as the general mean of all the $n(n-1)/2$ squared distances d_{ij}^2.

Consistently with the multi-tiered approach followed (i.e. 2-stages application of the clustering method: first to assess clusters of ERP needs and then to assess clusters of ERP capabilities within each cluster of ERP needs), we have applied the VRC procedure in three successive cases. The results are reported in Figure 9, and display the values of the VRC indexes from n = 2 to n = 8 for all the three cases considered.

The first step consisted in the application of the procedure to the entire sample of 75 firms to identify groups of companies that have similar ERP needs. The VRC indexes relative to this first cluster analysis (where the 6 environmental variables were used to discriminate among groups) suggested a two clusters solution as the optimal one, with the two groups composed of 46 and 29 firms. In the second step we used the 9 variables that define the development of ERP capabilities and we performed a second cluster analysis on the two groups that emerged from the previous step to identify companies that developed similar ERP capabilities. The application of the VRC procedure to this second case suggested that two sub-clusters ought be retained for each of the two groups above, hence providing a final solution with four clusters C12, C12, C21 and C22 composed respectively of 31, 15, 15 and 14 firms.

Figure 9 ABOUT HERE

6.4 Results: configurations of fit between ERP needs and capabilities

6.4.1 Discriminating power and statistical significance

The application of the analytical procedure described above to the sample of 75 firms uncovered 4 configurations of fit between the operational environment of the firms examined and the particular IT implementation strategy adopted, composed, respectively, of 31, 15, 15 and 14 firms. As correctly pointed out (Ketchen and Shook, 1996; Bensaou and Venkatraman, 1995), a second key methodological issue for the application of cluster analysis is "whether the configurational approach and the analytical procedure employed have any statistical power to distinguish among [the uncovered configurations]" (Bensaou et al. 1995, pag. 1480). To answer this question we have used Scheffe multiple contrast (Scheffe, 1959) and performed a series of one-way comparisons among the four configurations for all the 15 variables included in the original model. Table 19 reports the results of this exercise and suggests that all the variables included in the model (with the sole exception of customization and IT focus) strongly discriminate among groups (at $p < 0.05$ with a Scheffe contrast).

6.4.2 Descriptive validity

The second validation step of our procedure consisted in assessing whether a detailed analysis of the discriminating variables could portray specific characteristics of the configurations that offer insights under the light of the theoretical framework presented above. To this end, we analyzed the four configurations based on those variables for which the observed differences across groups were statistically significant. For reasons that will be evident from the discussion below, we propose the following denominations for the four groups:

- The frugal ERP
- The radical BPR
- The adaptive ERP
- The strait jacket[32]

[32] We want to thank a participant to the International Manufacturing Program at INSEAD for suggesting this analogy.

6.4.2.1 The frugal ERP

"Frugal ERP adopters" are companies that operate in stable environments, where both technology and market changes occur at a slow pace and - more importantly, along predictable trajectories. Products display long life cycles, thereby creating limited pressure on engineers for continuously modifying and improving design specifications. By the same token, these companies organize their production system in a made-to-stock mode, which leaves ample margins for long term planning.

The internal operational environment displays a high degree of homogeneity. The firms ascribed to this group are typically small or medium size companies that operate locally. Furthermore, even when they are part of larger multi-site organizations, the individual business units exhibit similar characteristics: they are often located in the same region, produce similar products or use the same distribution channels. In strategic parlance (Porter, 1986), they face weak forces for local responsiveness (i.e. limited need to adapt to the idiosyncratic characteristics of profoundly different markets). At the same time, they also face relatively weak forces for global integration, (they do not need to standardize their processes across many different units) because they mainly operate at a local scale.

In accordance to the principle of "requisite complexity" (Thompson, 1967), these firms respond to the above environmental requirements by deploying resources and by structuring their processes in a way that privileges efficiency and stability over responsiveness and continuous adaptation. For instance, by virtue of the relative predictability of their demand patterns that generate limited need for responsiveness, they can organize and manage their supply chains so as to emphasize efficiency and cost reduction. By the same token, their organizational structures are configured as relatively rigid bureaucracies, with a clear and formal definition of roles and responsibilities, which leave limited room for experimentation and organizational innovation. In such an environment the exploitation of existing capabilities is emphasized over the exploration of new and unknown solutions (March, 1991). Processes are based on highly codified routines, which are the product of knowledge accumulated over time and that continues to remain valid because the context where it was developed does not evolve rapidly.

VARIABLE	F(p)	Scheffe differences*
OPERAT. ENVIRONMENT		
Environmental dynamism	10.95 (0.000)	(1; 3,4) (2; 3,4)**
Environmental complexity	4.14 (0.009)	(1;3)
Environmental heterogeneity	17.23 (0.000)	(1; 3,4) (2; 3;4)
Product variety	3.93 (0.011)	(2;4)
Supply chain function	3.96 (0.011)	(2;3)
Organizational rigidity	3.72 (0.015)	(1;4)
ERP IMPLEMENTATION		
Consulting expenditures	6.70 (0.005)	(1; 3) (4; 2,3)
Team composition	14.11 (0.000)	(2; 1,3,4)
Consultant's role in IT support	9.07 (0.000)	(2; 1,4) (3; 4)
Consultant's role in BPR activities	4.88 (0.003)	(1; 2)
Explanation	3.17 (0.022)	(1; 4)
Involvement	12.52 (0.000)	(2; 1,3,4)
Software customization	(N.S)	
Focus	(N.S)	
Knowledge articulation	3.99 (0.013)	(3; 4)

* The notation (x; a,b,c) indicates that the configuration x is significantly different than configurations a, b and c.

** The numbers refer to the following configurations: 1 = Adaptive ERP; 2 = Straitjacket; 3 = Frugal ERP; 4 = Radical BPR

Table 19: Summary of the four configurations

Altogether, these attributes – both internal and external to the firm, generate limited requirements for "adaptive" ERP capabilities. On the one hand, the relative simplicity of the products manufactured and the homogeneity of the distribution process does not necessitate a particularly sophisticated information system that can handle large amounts of data and update them in a timely fashion. Similarly, a stable environment does not demand the organization to continuously reorganize its resource allocation scheme and to revise the configuration of its business processes to respond to unpredictable changes. Likewise, the relative homogeneity of products, processes and operations does not create special needs for the implementation of a common process platform in many different sites with different characteristics, which would necessitate a serious business process reengineering effort before and during the software implementation phase.

The IT capabilities developed by these organizations fully reflect the rather simple needs highlighted above and emphasize cost minimization. Well aware that an improvement of process performance would not offset the detrimental effect that an increase of their manufacturing and distribution costs will probably entail, these firms choose an implementation model that privileges cost reduction and minimization of complexity, even if this implies renouncing to potential process advantages.

The ERP strategy followed emphasizes speed of implementation and project simplicity. To do so, adopters deliberately decide to limit their business process reengineering efforts and the accompanying knowledge investments that these efforts would entail. To cope with the lack of internal IT competences, the development of "operational" knowledge is outsourced to external consultants, whereas the (limited) efforts to streamline operations are mainly managed in house.

Furthermore – and in line with the objective to minimize project cost and duration - end users outside the implementation team are given limited possibilities to participate in the process and to provide feedback. However, although it follows "command and control" logic, this implementation approach does not generate particular resistance to change inside the organization. The structured and somewhat rigid bureaucracy that regulates the functioning of the organization is compatible with the very same logic of the software, which is perceived as an incremental and competence-enhancing innovation (Tushman and Anderson, 1986). The emphasis on knowledge codification and process structuration that is typical of an ERP system is well perceived by the future end-users, who find a familiar working environment in the new software, even if they participate in a limited fashion to its design and implementation.

To summarize, this particular configuration somehow reflects a fit between limited ERP needs (both in terms of information processes requirements and of process optimization needs) and limited (or non-specialized) ERP capabilities. Accordingly, we name this configuration the *frugal* ERP, to reflect the fact that it correctly emphasizes cost reduction and rapid implementation over a more radical investment that would probably be inappropriate for the relatively basic environmental requirements.

6.4.2.2 The radical BPR

The environmental characteristics of this configuration closely resemble those observed for frugal ERP adopters. ERP adopters that follow a radical BPR approach are also small and medium size organizations that operate locally, in well-consolidated industries distinguished by technological stability and limited market turbulence. Competing successfully in such an environment requires the delivery of a limited range of durable products in an efficient fashion rather than the continuous introduction of new items. Hence, similar to the previous case efficiency and cost minimization are key priorities in the design and operation of business processes as opposed to responsiveness and prompt adaptation. Consistent with our observations for frugal ERP adopters, companies in this configuration display structured organizations too, where the execution of tasks is regulated by well-consolidated operational routines that exploit the knowledge accumulated and refined over time.

However, in spite of the relative similarity of their ERP needs, these firms follow an implementation strategy that radically differs from the one chosen by companies in the previous group, and decide to undertake significant investments to reconfigure their business processes and streamline their operations before migrating to the new system.

Pressured by the need to maximize efficiency, but relatively little concerned by the risk of losing organizational agility (because they operate in a stable and well-known environment), these firms recognize in the adoption of the software an opportunity to streamline their operations and to further integrate their business processes in search of improved effectiveness. Judging that the potential advantages engendered by a radical BPR effort will largely offset the additional cost that this very same effort may entail, they do not privilege a "low-cost, few-benefits" implementation strategy but heavily invest in the project throughout its development with the objective to realize a radical turnaround of their organization.

In these organizations ERP projects are characterized by a careful preliminary assessment of the adopter's business processes and by a detailed analysis of both its operational and IT needs which always precede the software configuration phase per se. By the same token, during this phase a large number of alternative software templates are analyzed in great detail before the ones that will ultimate support the new processes are chosen and implemented.

Furthermore, the delicate process through which the adopter achieves fit between the software infrastructure and its business requirements also follows a balanced approach. This fit is neither obtained by forcing the organization to spouse blindly some built-in templates, often preconfigured by external consultants. Nor is it achieved by developing ad hoc and fully customized add-ins, which were not originally included in the original software platform and which would enormously increase the complexity of the system and the risks of incompatibility with future upgrades and new releases. Conversely, integration is achieved through a concurrent process based on the simultaneous development of two efforts: on the one hand the new processes are designed after considering whether they could be actually supported by one of the many templates available. On the other hand, the simultaneous and detailed evaluation of a large number of these templates guarantees that no potentially superior configuration is inappropriately abandoned in favor of a suboptimal solution simply because the latter is easier to support through the software built in templates. To some extent this approach reflects the concerted change philosophy described in Miller and Frisen, (1982), as both the efforts to configure the software and those to assimilate the new organizational processes occur simultaneously (Robey et al., 2002).

Not surprisingly in such a strategy the role of consultants is important. However - and in sharp contrast to the straitjacket case, external consultants work in close collaboration with the internal experts and with future end users. Rather than to provide rapid and often poorly understood solutions to basic technical problems, they assist the adopter throughout its business process reengineering effort and facilitate the transfer of the operational IT knowledge that is necessary to support this effort.

Needless to say, such a radical endeavor requires the active participation of end users, who contribute both to the preliminary assessment of business needs and, also, to the design, structuration and pre-test of the new process templates.

6.4.2.3 The adaptive ERP

The "adaptive" ERP configuration reflects a fit between complex ERP needs and the development of extended competences during the implementation of the software. The characteristics of companies included in this configuration differ sharply from those of the two previous groups, with respect both to their internal structure and to the external environment where they operate. The first noteworthy distinction is that adaptive ERP organizations compete in high-clockspeed industries, where products have short life cycle, where technology evolves rapidly and where new and more successful business models developed by new market players continuously challenge those of the incumbent organizations. The degree of product and environmental complexity is also considerably higher than in the previous two cases. For instance, the number of product categories offered by a typical company in this cluster is significantly larger than that of the frugal or the radical BPR configurations, although it remains slightly narrower than that of the "strait jackets". Conversely, and probably because the type of items they manufacture and distribute resemble more to a commodity than to an innovative product in Fisher (1997)'s sense, these firms continue to privilege cost efficiency over responsiveness and customer service in their supply chain strategy.

The degree of isomorphism of the internal environment is also moderately low. Firms ascribed to this group are mainly representatives of large, multi-site organizations with an extremely diversified presence on the territory, often established in many different countries or even in different regions. In turn, this diversified presence implies very different needs in terms of products and processes, which have to be adapted to the requirements of the local markets. To some extent these firms operate in a context that closely resembles the "transnational environment" described in (Ghoshal & Nohria, 1990), which is characterized both by the need to promptly adapt to local requirements, and also, by the exigency to standardize and integrate processes across sites to benefit from scale economies.

Under these circumstances, the ability to respond to a broad range of different and often unpredictable situations while maintaining process efficiency is a necessary condition for survival. Not surprisingly, the internal structure of these organizations is designed to manage this type of complexity to favor exploration over exploitation and, ultimately, to facilitate adaptation to local needs. Hence, decentralization and autonomy become key priorities for these business units, which are organized according to loose bureaucracies, with a limited number of formal layers that guarantee only the minimal amount of structure necessary to guide the adaptation process.

Well aware of the challenging environment in which they operate, of the flexible *modus operandi* that they have developed to respond to these challenges, and, also, of the potential risks that a mismanaged ERP adoption may entail, these companies choose an implementation strategy that facilitates the generation of adaptive capabilities. Although initially mainly guided in their choice by technical reasons (such as the need to replace old legacy systems) adaptive ERP adopters do not consider the software as a mere IT system. Conversely, they are well aware of its potentially disruptive characteristics and plan their implementation accordingly. This strategy - which is executed by "planning centrally, analyzing specifically and deploying locally", requires large knowledge investments and it aims at minimizing the structural rigidities of the software while preserving the local autonomy of the business units where the latter is implemented.

Most of the efforts are dedicated to the development of a deeper understanding of the cause-effect mechanisms that determine the efficiency of processes at *local* level. The use of external consultants is also in line with this strategy. Despite their massive participation in the in the project they never act as pure technicians whose role is merely that of configuring the system in the minimum amount of time. Conversely, they actively participate in the complex business process reengineering effort that precedes the implementation per se and facilitate the adaptation of the software to the local needs of the organization.

It is worth noting that most of the software configuration also occurs locally. Albeit most companies in this group are part of a larger organization, they seldom profit from the services of an internal ERP competence center that designs and standardizes the process templates in a centralized fashion. Even when such a center exists, its role is simply to provide very general guidelines to the local subsidiaries, which are then free to choose the configuration that best suits their needs, within the range of possibilities offered by standard templates.

In line with this approach, the implementation occurs in a participative manner, following the principles of fair processes. Future end users are heavily involved in the implementation process and provide continuous feedback to ameliorate the system and adapt it to the local needs of the organization. Although longer, more costly and probably riskier, this strategy ultimately facilitates the development of a solid process knowledge repository at the local level, which is the necessary condition for adaptation to occur.

6.4.2.4 The "strait jacket"

Similarly to the "adaptive ERP" case, this configuration also includes companies that exhibit complex ERP needs, both in terms of information processing and process optimization requirements. These business organizations operate in turbulent environments[33], where products display short life cycles and where pressure from competitors is such that only the offering of an extremely wide range of product categories and the continuous introduction of new models onto the market would guarantee survival (not surprisingly, organizations ascribed to this group derive a significant part of their annual revenue from new products). The degree of environmental isomorphism is also particularly low: albeit most of these firms are part of larger multinational groups that operate in different countries, the different sites display very little commonality among each other, both in terms of products produced and of their internal business processes.

The above characteristics generate pressure to prioritize responsiveness over efficiency in the production and distribution systems, which are both designed to cope with sudden demand variations and to respond to the requirements of local markets, even at the risk of incurring higher costs. Furthermore, as production is mostly organized in a made-to-order fashion, schedules are subject to frequent modifications, which introduce an additional element of instability in the firm's business landscape. According to Ghoshal and Noria (1990)'s taxonomy, one could say that these characteristics resemble those of a multinational environment, where the forces for local responsiveness are extremely strong and overcome those for global integration. That is, firms that operate in such a context would certainly obtain cost

[33] The degree of market turbulence for this configuration is only marginally lower than that of companies in the "adaptive ERP" configuration. Furthermore, the difference is not statistically significant.

benefits from the standardization of their processes. However, the benefits potentially achievable would be largely offset by the lack of adequacy to local market needs that the standardization effort would produce.

Not surprisingly, firms in this group decided to cope with the turbulence and the complexity of their business environment by creating adaptive organizational structures, characterized by few hierarchical layers, informal behaviors and non-codified relationships among different members. Similarly, the relationship subsidiary – parent company is organized in a decentralized fashion, with individual business units enjoying a large degree of autonomy from the headquarters.

However, in spite of these relatively complex IT needs, which suggest that the development of adaptive ERP capabilities would probably be more appropriate, companies in the strait jacket cluster follow a radically different implementation strategy. Concerned by the challenges generated by their operational environment, which doubtlessly require dedicated information systems able to accurately process a large quantity of data in an extremely timely fashion, these firms perceive the ERP implementation as the ultimate solution to their IT problems. They also consider it as a unique opportunity to replace a multitude of legacy systems with a simpler integrated solution. As a matter of fact, adoption decisions in this configuration are mainly driven by "local optimization" purposes rather than by business process re-engineering needs. The ERP implementation is therefore perceived as an instrument to ameliorate specific operational areas rather than as an opportunity to streamline process across the entire organization. As a consequence, the potential process integration advantages generated by the software are often overlooked if not completely neglected, along with the potential risks that they may entail.

However, concerned by the enormous costs and duration of typical ERP projects and probably misguided by the numerous horror stories on implementation failures, these companies decide to simplify the software configuration and minimize the complexity of the system by "planning centrally, developing centrally and imposing locally". In order to minimize cost, the common procedures are designed and developed in a general competence center by a restricted group of internal IT experts, then implemented locally with very limited participation from the future end users, who have virtually no possibility to provide feedback, nor to influence the process. In line with the cost minimization strategy adopted, both operational and conceptual knowledge are developed internally, but very little time and resources are dedicated to the delicate phase of analysis that should precede the implementation per se. Hence, although ERP capabilities are generated – at least in principle, in house, they remain superficial and are mostly limited to the technical domain. Very little effort is made to examine the cause-effect relationships that determine the efficacy of a business process. Similarly there is virtually no attempt to use the ERP implementation as an opportunity to reengineer business processes.

The limited reliance on external consultants could suggest that these companies privilege the development of in-house capabilities. However, this is very seldom the case, for two reasons. First and foremost the in-house development approach is driven more by the need to reduce cost, than by that to develop a solid knowledge repository inside the firm. Second, the limited involvement of end-users limits the development of these competences where they would be most needed (i.e. in the local business units that face continuous pressure to update the ERP-based business processes when market conditions change).

Hence, the "strait jacket" configuration reflects a lack of fit between complex information processing needs (high environmental instability) and a diversified environment (many sites with often different requirements) and the development of simple ERP capabilities, resulting from a centralized - yet superficial and inexpensive, implementation strategy.

6.4.3 Predictive validity

To maximize the external validity of the results, i.e. to minimize the risk that -- in spite of the methodological rigor adopted to derive the classification, the latter will not offer insights into the general phenomenon studied – we have assessed the validity of the classification against an external criterion (criterion-related validity: (Ketchen and Shook, 1996). The objective is to examine whether the proposed grouping provides unique insights to explain differences across organizations along a particular criterion, in addition to what the individual variables used to derive the taxonomy can generate. Accordingly, we examined whether the classification derived from our model was useful to explain performance differences across adopters, which could not otherwise be justified by means of the individual variables used to derive the taxonomy. To this end, we conducted a series of one-way analyses of variance using a new set of measures as independent variables and the cluster to which each firm belongs as an explanatory variable.

To take fully into account the fact that the benefits or the negative consequences of an ERP implementation may be observed at different levels (project management, IT and operational) and that achieving success in one dimension may not necessary guarantee positive results in different ones we examined performance differences among groups along four distinct dimensions:

- Changes in information quality
- Operational improvements
- Acceptance
- Degree of goal achievement

"Changes in information quality" measure the extent to which the software implemented achieved its primary technical objective, i.e. whether it provided the adopter with more accurate, timely and more useful information than the systems that were in place before. In relation to our stylized model, this indicator should reflect the extent to which the system responded to the information processing needs of the organization.

The degree of "operational improvement" considers the second broad dimension that we retained in the model, i.e. whether the system satisfies the process optimization needs of its adopter. To this end, the measure used evaluates the degree to which performance has deteriorated or improved one year after the system went live in three critical areas (procurement cost, inventory cost and software maintenance and upgrading costs).

To take into account the fact that ERP adoptions are often undertaken for a variety of reasons, which are difficult to disentangle and evaluate separately, we also included a more general performance measure, namely the "the degree of goal achievement". This assesses the degree to which the project has achieved its *stated* objectives respectively three months, one year and two years after the live date.

Finally, as resistance to change is often mentioned as one of the ultimate reasons for the failure of IT projects we felt that it was appropriate to consider this aspect and assess the organizational impact of the innovation. Accordingly, the degree of "acceptance" measures the extent to which the new system was or was not favorably accepted by end users, i.e. by the individuals who were ultimately expected to benefit from its introduction. The scales used to measure the above variables are summarized in Table 20.

VARIABLE	N. items (alpha)	Items
PERFORMANCE MEASURES		
Operational improvement	3 (.71)	Change in inventory holding costs Change in procurement costs Change in software maintenance costs
Degree of goal achievement	3 (.91)	% of stated objectives achieved after 3 months % of stated objectives achieved after 1 year % of stated objectives achieved after 2 years
End-user acceptance	4 (.78)	Length of ERP "ramp-up" time Willingness to execute new tasks Understanding of the system logic Overall degree of acceptance
Changes in Information quality	3 (.71)	Extent to which information is more/less: (i) more timely; (ii) accurate; (iii) tailored to needs;

Table 20: Operational measures for performance indicators

Table 21 displays the results of a pairwise comparison among the four clusters with respect to the four performance measures retained. Only performance differences significant at the 5% level with a Scheffe contrast are reported in the table.

The results of this comparison suggest several interesting observations. First and foremost, they confirm that the configurational analysis offers some useful insights to explain the differences observed across groups of adopters with respect to the four dimensions retained. To this end, we found highly significant differences across the four configurations (the F-values for the four scales are respectively $F_{info} = 5.16$, $F_{goal} = 5.14$, $F_{acceptance} = 3.56$, significant at the 1% level and $F_{oper} = 2.80$ significant at the 5% level).

Second, it highlights that non-negligible performance differences exist across configurations, although not to an equal extent for all the four cases and with respect to all the indicators retained. The first relevant finding is that the "strait jacket" clearly emerges as the low-performance relationship, for all the indicators considered. Although somewhat less sharp, some differences are also visible among the three high performance configurations, with the radical and the adaptive ERP being generally superior to the frugal one, at least in some areas. The adaptive and the radical configurations consistently display higher information quality improvements than the other two clusters.

The group of radical ERP adopters is also superior with respect to the degree to which employees accept the system and with respect to the magnitude of their operational improvements. Conversely, it exhibits significantly lower degrees of goal achievement with respect to the adaptive and the frugal configurations.

In relation to our initial stylized model, the frugal configuration reflects therefore a fit between relatively simple ERP needs and the development of equally simple capabilities. Not surprisingly companies in this group report high level of goal achievement (because objectives that aim at cost-reduction such as the integration and standardization of procedures were among the primary goals). However they also achieve limited operational improvements, because achieving the latter would have required a significantly greater BPR effort than the one actually deployed.

Similarly, adaptive ERP adopters reflect the existence of fit between complex ERP requirements and the generation of advanced capabilities, which are based on a radical analysis of operations and on the development of specific process knowledge. Hence, in spite of the far more demanding needs that they face compared to other ERP adopters, these companies manage to achieve important improvements by adjusting the level of their knowledge investments to match the requirements of their operational environment.

In sharp contrast with firms in the frugal configuration, radical adopters respond to relatively simple requirements by generating complex capabilities and by engaging in a radical BPR effort that resembles that undertaken by adaptive companies. Based on the previous analogy, one may suspect that this configuration reflects a misfit between limited ERP needs and radical ERP capabilities and this misfit would generate a negative impact on performance. However, this is not the case: albeit this strategy may represent an unnecessary investment, the massive BPR efforts undertaken by these companies enable them to radically streamline their processes and to achieve higher operational improvements than firms in other configurations.

Finally, straitjackets also reflect a misfit between needs and capabilities, but with far more disadvantageous consequences on performance than radical adopters. Faced to a complex and ever-changing environment, where process adaptation and organizational agility are necessary conditions for success, these firms limit their IT investments and develop simple and highly structured ERP capabilities. In this particular setting, this strategy has obvious drawbacks. First of all the implementation of process templates in a "pre-configured" fashion further enhances the structural rigidities of the software, thereby hampering process adaptation and reducing organizational agility, both of which would be badly needed in such a context. Furthermore, the particular deployment model adopted –based on centralized design of procedures and on their rigid implementation at the local level, is not well suited to organizations that mostly include multiple sites with different specific requirements. In this setting, the efficiency gains generated by standardization are largely offset by the additional costs engendered by the lack of fit between the new procedures and the local conditions where the individual units operate. Finally, the top-down implementation model chosen clashes with the fluid organizational culture that is typical of these firms, and it augments the end users' difficulties to intervene on the system when modifications or adjustments are necessary.

It is important to note that the complementarity between the ERP needs and the capabilities developed seemed to determine the effectiveness of the implementation more than the individual variables by themselves. Indeed, although it appears that ceteris paribus the presence of complex ERP needs demand more intense efforts to achieve the desired objectives, we have found both high performing and low performing configurations that operate in this environment. By the same token, albeit simple and stable environments are likely to be a more fertile ground for an ERP implementation, we have also observed significantly different results for firms that followed opposite implementation strategies.

Focal configuration \ Compared to	*ADAPTIVE*	*STRAITJACKET*	*FRUGAL*	*RADICAL*
(ADAPTIVE)				
STRAITJACKET	Lower operational improvements, lower information improvements, lower degree of goal achievement and end-user acceptance relative to adaptive ERP			
FRUGAL	Lower information improvements relative to adaptive ERP	Higher operational improvements, higher information improvements, higher degree of goal achievement and end-user acceptance relative to straitjacket		
RADICAL	Lower operational improvements and lower degree of goal achievement relative to adaptive ERP	Higher operational improvements, higher information improvements, higher degree of goal achievement and end-user acceptance relative to straitjacket	Larger information improvements, higher end-user acceptance, and higher operational improvements relative to frugal ERP. Lower degree of goal achievement relative to frugal ERP	

Table 21: Predictive validity: pairwise comparisons between configurations. The table cells indicate statistically significant differences between the configurations in the row headings and the configurations in the column headings.

6.5 Conclusions

The stylized conceptual framework that we had initially developed suggests that companies that consider adopting an integrated information system should replace the question "which is the most effective implementation strategy?" with the more appropriate one "which strategy best fits the business requirements of our organization?". The analysis of over 80 ERP projects conducted by European and US manufacturing firms in the last six years indicates the existence of four typical configurations that reflect different operational environments and different intensities for the knowledge investments undertaken during the implementation of the software (Figure 10). It also indicates that these different strategies may display different degrees of efficacy, depending on the specific operational environment in which they are implemented. However, the analysis suggests that the posited contingency effect does not seem to hold evenly for the two archetypal knowledge investment strategies that we have found to be most common across adopters.

Figure 10 ABOUT HERE

First and foremost it is quite evident that complex and dynamic environments generate ERP needs that are more difficult to satisfy than those produced by simple and stable operational contexts, regardless of the implementation strategy chosen. These needs require the system – which is de facto a global process integrator, to favor organizational agility and adaptation at the local level. Ceteris paribus, simple and stable conditions are likely to be more compatible with the integrative nature of the technology and appear a more suitable ground for its adoption.

That said, it is also quite evident that the returns generated by the two strategies followed to develop ERP capabilities are different, and that the magnitude of this difference is influenced by the environment in which they are implemented. On the one hand, generating adaptive ERP capabilities built upon deliberate knowledge investments that favor the generation of internal competences seems to be more likely to guarantee an increased operational performance, even for companies that operate in stable environments. On the other hand, it is also clear that the differences between this approach and the more conservative one that neglects process knowledge are considerably more significant in companies that have complex ERP needs. As a proof, the performance differences between adaptive ERP adopters and straitjackets are much larger than those between the frugal and the radical adopters (which both operate in a stable environment and follow the same antithetical implementation models).

Hence, developing complex ERP capabilities and competing in turbulent and complex environments seem to be supermodular strategies (Milgrom et al., 1991; Milgrom and Roberts, 1990): the returns generated by increasing knowledge investments augment with an increase of the degree of complexity and turbulence of the environment. This is tantamount to saying that in such a situation the dangers of underinvesting in an ERP implementation are significantly more important than in a stable setting. Whereas companies that have simple requirements can afford "vanilla[34]" ERP implementations, firms that operate in unstable environments must be really careful in doing so. Hence, if concerned by the risks and the cost associated with a "full implementation", they should probably consider whether to adopt the system at all, rather than to compromise and adopt a low-cost solution that entails a number of additional disadvantages, especially in the long run.

It is interesting to analyze our findings through the lens of the dynamic capability paradigm and through that of studies on knowledge and learning.

To some extent these results seem to partially contradict the widely accepted belief that simple and unstructured routines are more useful to develop effective dynamic capabilities in extremely turbulent environments. It must be noted, however, that the analogy has some limitations and must be interpreted with care. In the particular case considered here, the knowledge articulation efforts (whose magnitude depends upon the amount of process analysis conducted by the firm during the implementation of the software) are always accompanied by an *implicit* codification process, which is embedded in the very same logic of an ERP system. That is, our sample does not contain organizations that have chosen to limit codification, but only

[34] In the ERP jargon, this term defines projects where BPR and software customization efforts are limited to a minimum or affect only few business processes (Davis, 1998).

firms with highly codified processes that have or have not decided to undertake knowledge articulation efforts.

In this context, a knowledge codification process that is accompanied by articulation efforts is always beneficial, regardless of the particular environment in which it takes place. Conversely, the efficacy of codification efforts that are *not* effectively supported by a preliminary phase of articulation remains contingent on the degree of turbulence of the firm's operational environment and it is particularly low for high clockspeed industries. In turbulent environments the firm typically codifies its business processes at a specific point in time, but without a proper understanding of the cause-effect relationships that influence the outcome. If the reference scenario mutates, it may continue to operate in accordance to the processes already codified, without being able to fine tune them for the new situation, precisely because it lacks the specific knowledge about why, what and how should be modified.

This interpretation also offers an interesting analogy with (Lapré et al., 2000), which analyzed the relative effectiveness of four learning strategies deriving from the combination of high/low levels of operational and conceptual knowledge. In our particular case, "operational knowledge" corresponds to the technical IT skills that all ERP adopters are *de facto* obliged to develop, and it is high *by default* in all the configurations studied. Conversely, "conceptual knowledge" is equivalent to the process analysis efforts undertaken during the software implementation and varies according to the particular configuration strategy chosen.

Consistently with the above-mentioned study, learning efforts that entail the development of both operational and conceptual knowledge produce the largest improvements even in the particular context of an ERP implementation. Conversely, in this setting strategies that neglect the conceptual aspect of learning and emphasize only the operational ones have mixed effects. Whereas such an approach is harmless in steady environments, where the relative stability of the underlying reference system renders repeated adjustments based on a trial and error strategy still possible and effective, it is extremely dangerous when the very same reference system shifts continuously and unpredictably. In the latter situation only a precise understanding of the cause-effect relationships that regulate the functioning of a business process may enable the firm to rapidly implement the most appropriate solutions to the problem faced.

The results have also interesting managerial implications. Companies that operate in complex and turbulent markets, characterized by rapid technological changes, unpredictable demand patterns, and by the continuous emergence of new business models should consider whether an ERP implementation is appropriate at all, even before discussing the type of implementation to adopt (not to mention the choice of a particular vendor). They should also consider whether they possess enough resources/expertise to conduct a radical reengineering of their processes and to accompany the process codification efforts with appropriate upfront investments is process analysis.

Conversely, firms that operate in very stable environments and have limited needs for integrating their processes across different locations should consider whether the results of a full-scale implementation would be worth the efforts and the investments they require.

Chapter 7

Conclusions

7.1 Contributions

In the first chapter of this dissertation we observed that - while corporate IT spending continues to increase - the operational and financial value of information systems is still being questioned, at many levels. We also noted that it is not appropriate to refer to an IT paradox "tout court", because the relationship between IT innovation and economic and operational performance is neither simple nor univocal. Horror stories are almost as numerous as examples of companies that profited from an IT innovation to improve their operational capabilities.

Hence, while many companies struggle to maximize the returns of their IT investments, both anecdotal evidence and academic research suggest that we still have a limited understanding of the complex mechanisms through which the implementation of large information systems affect the operational and the economic performance of business organizations. This knowledge gap has important practical consequences, because companies are often obliged to adopt specific IT strategies without a solid understanding of the underlying phenomena that may render them either effective or inappropriate for the particular case at hand.

These observations constituted the point of departure of our investigation. Using enterprise planning systems as a representative example, this dissertation aimed at shedding further light on the relationship between IT innovation and performance, by addressing three specific questions:

1. What are the mechanisms through which the adoption of an IT innovation affects operational effectiveness and – possibly – generate sustained competitive advantage?
2. Is the impact of IT adoption contingent to the specific organizational and industry environment in which the adopter operates?
3. What are the phenomena and the cognitive mechanisms that subsume the generation of IT capabilities?

Clearly, this work is only a first step towards the achievement of these objectives. Yet, it provides several important contributions. The first general contribution is a unified view of the process through which complex IT systems affect business and operational performance. Our analysis reinforces the hypothesis that most IT systems - and ERP in particular - cannot be just considered as mere transactional instruments. They are corporate infrastructures whose impact spans well beyond the mere information technology domain and touches upon the very sources of operational excellence.

The framework displayed in Figure 4 provides a useful scheme to place our results into a unified structure and to relate them to the three main research questions we wished to answer.

As a first step, we argued that the adoption of an IT system affects the business performance of an organization by means of two primary effects: i) a modification of the operational performance of the processes supported by the software; ii) a modification of the degree to which the adopter's main competitors can imitate or assimilate its new processes. These two effects are strongly intertwined as they originate from the fact that many IT systems (and ERPs in particular) make extensive use of processes templates. Although it helps firms streamline operations and achieve operational and administrative efficiency, the widespread use of these common "reference models" also exposes ERP adopters to higher risks of imitation, especially if no customization strategies are adopted to create idiosyncratic IT capabilities. "Ceteris paribus" (i.e. controlling for other drivers of competitive advantage) the relative magnitude of these two effects is likely to determine the long-term impact of an ERP adoption on business performance.

As a second step, in the attempt to identify the sources of IT-driven operational excellence, we demonstrated that operational improvements do not arise *ipso facto* from the information quality improvements that systematically occur after the roll out of an enterprise system. Rather, they are mainly the consequence of the fact that an ERP adoption interferes with the knowledge evolution cycle through which the firm generates dynamic capabilities. Operational improvements in post-ERP environments are indeed driven by the modification of two antecedents of this construct at the process level: efficiency (i.e. the ability to utilize a minimum amount of time and resources to execute basic tasks) and flexibility (i.e. the ability to promptly operate process and organizational changes in response to modifications in the external environment). Therefore these two properties come forward as the true constituents of the dynamic capability construct at the operational level.

The empirical analysis developed in chapter 5 also enabled us to answer the second general question discussed above. Indeed, our results suggests that the impact of this technology-specific effect (modification of process efficiency and flexibility) may be amplified or attenuated by organizational and market contingencies that shape the nature of the operational environment in which the system is implemented. These observations are in line with findings from other studies that identify the characteristics of the external environment (Soh et al., 2000) and internal firm-specific factors (Abdinnour-Helm, 2003) as two important moderators of ERP implementation processes.

Our analysis suggests that the pre-implementation organizational attributes of the adopter play an important role in the process. This is not a surprise, because an ERP adoption takes place inside an established organization, with its codified behaviors, routines and rooted working habits, which naturally interfere with the knowledge codification processes that accompany the rollout of the software, therefore amplifying or attenuating its impact. We disentangled two specific organizational attributes, which display antithetical effects: the degree of organizational rigidity and the degree of codification of organizational procedures. Whereas organizational rigidity impact performance negatively, the existence of codified procedures suggests itself as an enabler, rather than a hurdle, for the achievement of operational improvements. Given that an ES implementation is *de facto* a knowledge codification process, companies whose knowledge repository was already extremely codified and structured in the pre-ERP era are more likely to perceive the innovation as a competence-enhancing rather than as competence-destroying one (Tushman and Anderson 1986). Hence, the fact that they face lower knowledge barriers to assimilate the new ERP-based processes (Robey and Ross, 2002) naturally enables these companies to profit from the new technology to rapidly move towards a superior efficiency frontier.

Second, we also noted that market dynamism influences the processes studied, both because highly dynamic markets clearly constitute a more demanding environment for the implementation and the use of complex and "bulky" software, and because this variable displays a moderating effect on process flexibility and efficiency. However, and in contrast with our expectations and with the common conceptualization of the dynamic capability construct, process flexibility seems to be less valuable in turbulent markets than in stable industry sectors. This apparent paradox can be explained by considering that firms that operate in extremely dynamic settings often conduct excess exploration (i.e. excess experiential search). In such contexts, the cognitive efforts required by the implementation of an ERP may indeed constrain this process and prevent firms from wasting resources in the search for sub-optimal alternatives (Gavetti and Levinthal 2000).

Having established the nature of the capabilities that favor the achievement of operational excellence and the main factors that influence their effectiveness, we naturally turned our attention to the third general question outlined in the introduction, i.e. the identification of the mechanisms that subsume the generation of these competences.

Mindful of the fact that an IT implementation requires important cognitive efforts (Davenport and Short, 1990), and that it facilitates the evolution of a firm's knowledge repository from the individual level, to the group level and to the organization level (Jiang et al., 2001), we recognized that the investments in knowledge articulation and dissemination conducted during the software configuration phase are among the primary constituents of the IT capability-generation mechanisms. Articulation efforts reduce causal ambiguity and facilitate the development of process knowledge both at the individual and at the group level. Similarly, the type of knowledge dissemination efforts has a profound impact on the nature of capabilities developed. For instance, by inducing voluntary cooperation both among employees and between consultants and employees fair dissemination strategies (Kim and Mauborgne, 1995) that envisage the active involvement of end users favor the development of operational and conceptual knowledge, thereby further facilitating processes of organizational adaptation. Conversely, non-participative implementation models are likely to be fertile grounds for the growth of coercive bureaucracies, which hamper adaptation.

However, in line with the environment-fit perspective, we also recognized that even knowledge investments should spouse the specific needs of the adopter. Indeed, the model developed in chapter 6 supports this perspective. On the one hand the results suggest that the magnitude of the knowledge articulation and dissemination efforts undertaken during an IT projects and the type of implementation strategy chosen (coercive vs. enabling) have a profound influence on the degree of post-implementation performance. On the other hand - and in line with previous research on organizational configurations (Bensaou and Venkatraman, 1995) – our results also challenge the notion of "best practice" and indicate that these efforts should be calibrated to match the particular requirements of the adopter. For instance, they indicate that, whereas strategies based on limited knowledge investments and on a coercive logic are still effective in steady environments, where the relative stability of the underlying reference system renders repeated adjustments based on a trial and error strategy still possible, they become intrinsically hazardous when the competitive landscape shifts continuously and unpredictably.

By addressing the above questions this work provides a contribution to several research streams. First and foremost, it naturally integrates the literature on the IT productivity paradox by opening the "black box" and identifying the organizational processes that generate IT-driven operational improvements. Following the call for further research that bridges the gap between systems-oriented and concept-oriented works on ERP systems (Jacobs et al. 2003) and in line with recent developments in this area (Bharadwaj, 2000), this dissertation applies a new perspective (the resource-based view of the firm) to study a set of phenomena that had so far mainly addressed from a technical or economic viewpoint. That is, rather than following a pure econometric approach it adopts a strategic and organizational angle to explore the intermediate process variables that link in a causal fashion IT investments to operational effectiveness. Also, by doing so it highlights the fact that IT-driven performance changes are not just the causal consequence of a new technology adoption, but also the result of precise and deliberate managerial choices operated throughout the system implementation phase.

Second, the research also makes some contributions to the dynamic capability paradigm. Since its initial conceptualization (Leonard-Barton 1992; Pisano 1994) this perspective was criticized because it received little empirical verification. Hence by deriving a set of specific measures that can be used to quantify this construct at the operational level, the present work helps transfer this paradigm from a pure theoretical level to a more operationally oriented and empirically testable ground. Furthermore, it completes and extends the work of Zollo and Winter (2002), and it provides a further empirical verification of the relationship between knowledge investments and the development of organizational routines in dynamic settings.

In particular, our results further clarify the role of knowledge codification and learning investments in relation to the development of dynamic capabilities. Whereas common wisdom suggests that experiential learning and trial-and-error strategies are best suited to cope with extremely turbulent settings, our analysis emphasize the importance of developing accurate cognitive models and of codifying these models into process templates, even when the competitive landscape is continuously shifting. This occurs because the cognitive efforts developed during the phase of gap analysis by companies that follow radical ERP implementation strategies have an ambivalent role. They are "useful not only in seeding the process of experiential search on a particular location in the fitness landscape but also in constraining the process of experiential search from wandering to less attractive regions of the landscape" (Gavetti and Levinthal 2000, p.133).

Finally, although the framework proposed may be applied to IT innovations in general, the research contributes to extend our specific knowledge of enterprise systems. By providing an integrating framework that examines the entire life cycle of an ERP system and by disentangling a structural effect from the impact of the implementation strategy, this study further precise the risks and the advantages associated with the adoption of this technology. In this sense it represents a first step towards the development of more comprehensive research that addresses not only basic ERP implementation problems but, also, the issue of how these systems can generate operational and strategic benefits (Jacobs et al., 2003).

7.2 Managerial implications

By shedding some light on the complex phenomena that link IT adoption, organizational learning and operational effectiveness, and by distinguishing between structural and firm-dependent factors, this work provides useful insights both to ERP adopters and software vendors.

ERP adopters - who are constantly faced with the challenge of implementing and using IT systems of ever-growing complexity and size – can profit from this research both to understand whether the adoption of such a technology is appropriate at all for their particular needs and, also, to design optimal implementation strategies that minimize some of the structural risks of the system. The key message to managers from this research is quite clear: the implementation of complex IT systems and particularly that of an ERP requires a holistic approach. Merely increasing the level of IT investments without developing IT capabilities will not secure the achievement of long-lasting operational benefits. Similarly managing the sole software configuration phase may reduce the risk of experiencing budget overruns and shorten project lead times, but it is not sufficient - by itself – to guarantee that the new technology will contribute to the generation of sustained competitive advantage. The impact that the system exerts on the dynamic capabilities generation mechanisms - emphasized in chapter 5 - must induce a potential adopter to consider the implementation of these technologies vis à vis both its strategic goals and its organizational and operational environment.

Similarly, the analysis of the relative effectiveness of the different implementation models developed in chapter 6 challenges the notion of "best practice" and suggests that both the assimilation and the configurational knowledge barriers that occur during the implementation must be addressed idiosyncratically, after considering the specific ERP needs of the organization.

Software vendors can also profit from the results to distinguish more precisely the structural weaknesses of the technology currently in use and to design future generations of ERP systems in which the shortcomings of the present one are significantly reduced. Furthermore, they can also use the proposed contingency framework to identify the customers that are potentially most valuable (i.e. those whose characteristics are most suitable for the implementation and the actual use of an enterprise system).

7.3 Avenues for future research

Our work has just touched upon the surface of an extremely vast and complex phenomenon. Several questions remain unanswered and deserve further investigation. First and foremost it should be noted that – although they includes variables that are not idiosyncratic to the ERP context - the models that we proposed have been tested by examining companies that adopted a particular product (SAP R/3). Hence, further research would be appropriate to verify whether our findings can be generalized and extended both to ERP products from other vendors and, especially, to other types of software beyond the ERP domain.

Second, in this work we deliberately restricted the scope of our empirical analysis to the organizational and operational impact of IT adoption, thereby overlooking the question of whether these systems facilitate or hamper the achievement of sustained competitive advantage. Indeed, as discussed in chapter 3, while we expect that the adoption of an ERP may increase profitability through the benefits that it generates at the operational level, we also recognize that other forces may have an antithetical effect. For instance, the adoption of standardized process templates may expose some ERP users to the risk of being more easily imitated by direct competitors who adopts similar products with similar configurations. This obviously reduces the probability of generating long-lasting competitive advantage.

The case studies discussed in chapter 2 also point out a number of unresolved problems and indicate additional avenues for research. Multinational organizations provide perhaps the most interesting challenges. Pressured by the need to increase their level of agility while maintaining some degree of administrative efficiency, large organizations that undertake multi-site implementations are still confronted with the issue of determining the optimal degree of process standardization across different sites. The "differentiated standardization" solution adopted by Atom is clearly a solution to this problem. Yet, it is not clear under what general circumstances such an approach would be viable and what the operational challenges of its practical implementation are. To this end, developing analytical models that quantify in a precise fashion the different costs and advantages involved in each alternative would certainly provide useful insights.

Finally, - although ERP systems are likely to remain the principal "transactional backbone" for many organizations in the years to come - it is quite evident that the advent of a new generation of systems creates new challenges for business organizations and, correspondingly, poses new and more interesting questions to management scholars (Akkermans et al., 2003; Jacobs et al., 2003). For instance it is still unclear whether the use of systems and applications that extend beyond the firms' gates and connect business partners in seamlessly integrated supply chains accentuates or attenuates the phenomena that we described in this work. On the one hand it is likely that the intra-organizational cognitive mechanisms that we analyzed are amplified when transferred at the inter-firm level, thereby further increasing the differences across adopters that follow different configuration strategies. On the other hand, the increasing pressure to contain IT costs and the perception that coordinating projects across different firms may entail additional risks may suggest adopters of future generations of IT systems to revert to simpler and more standardized approaches.

Given the strategic role that these technologies play in modern business organizations we believe that these questions should not be overlooked. Addressing them will indeed help companies better evaluate the risks and the opportunity of designing and operating their IT infrastructures and further enhance the operational and competitive benefits that these systems may generate.

Appendix 1: References

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Appendix 2: Figures

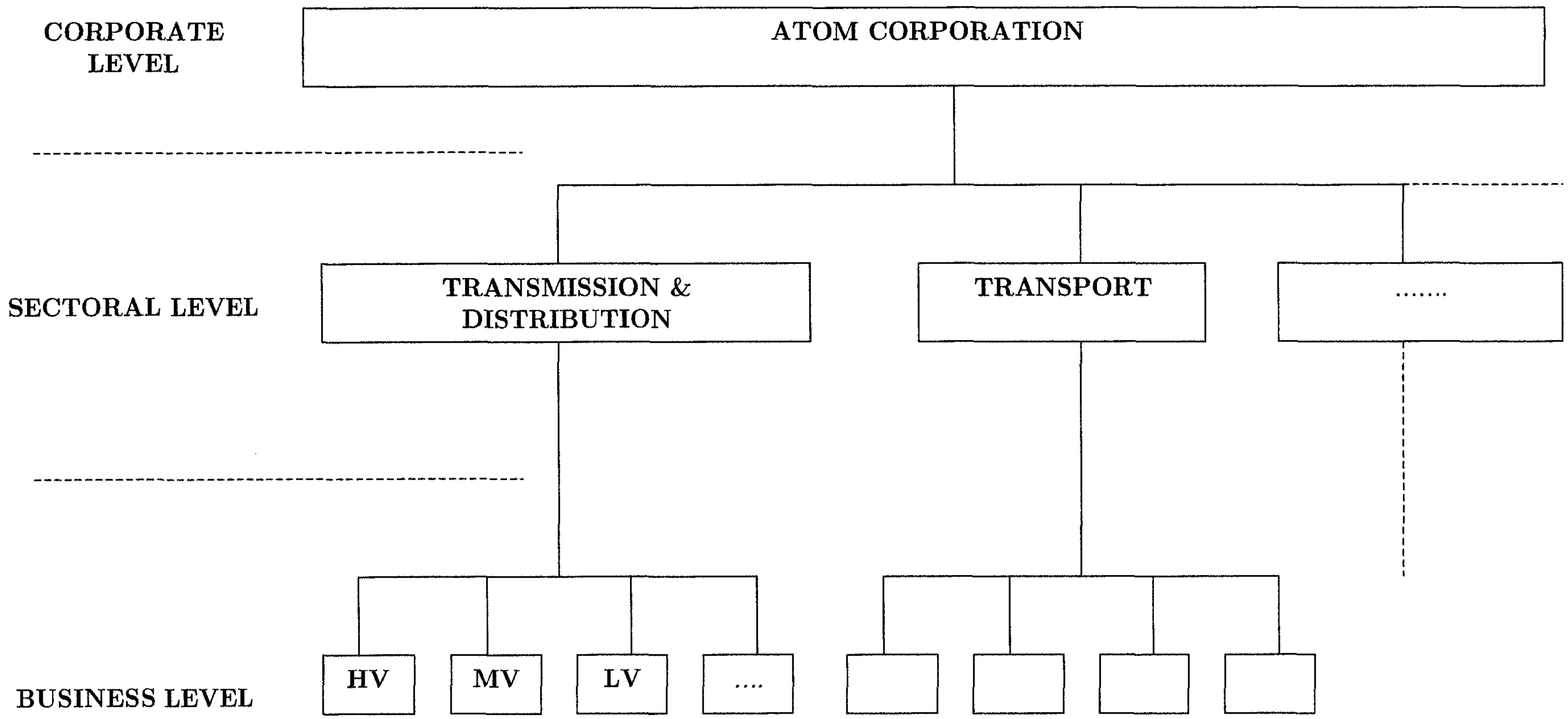

Figure 1: Atom organizational structure

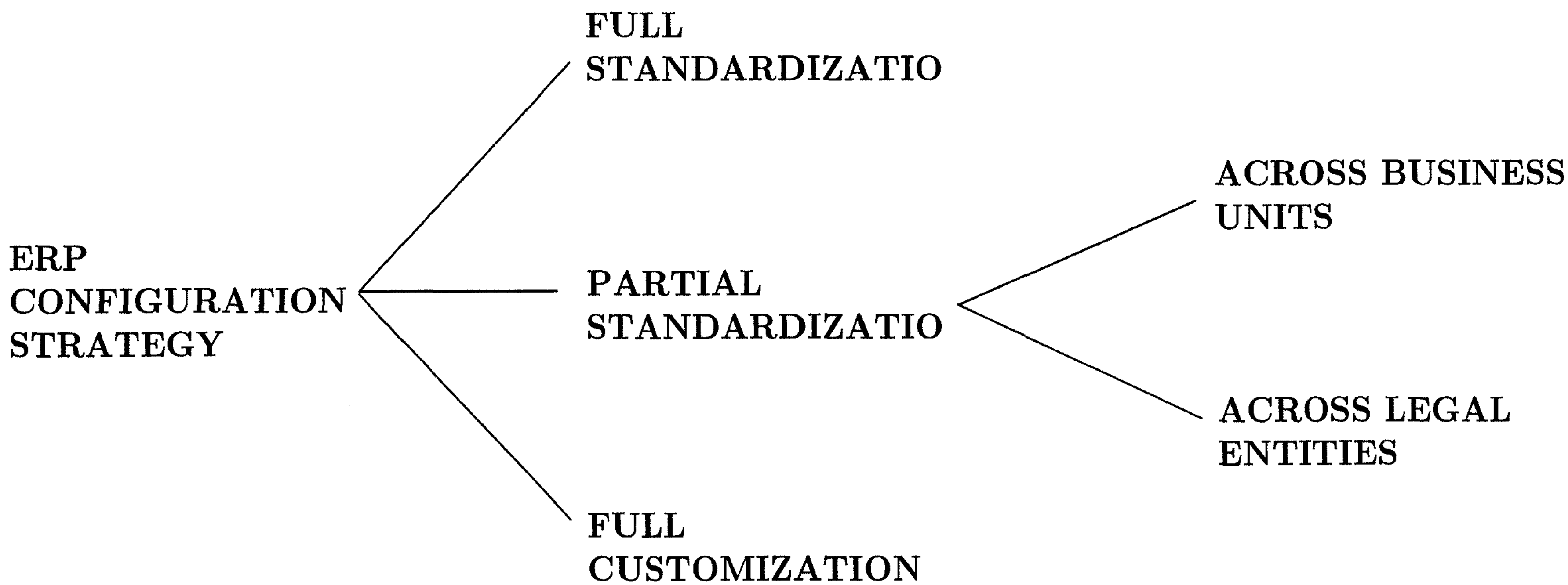

Figure 2: ERP configuration strategies at ATOM

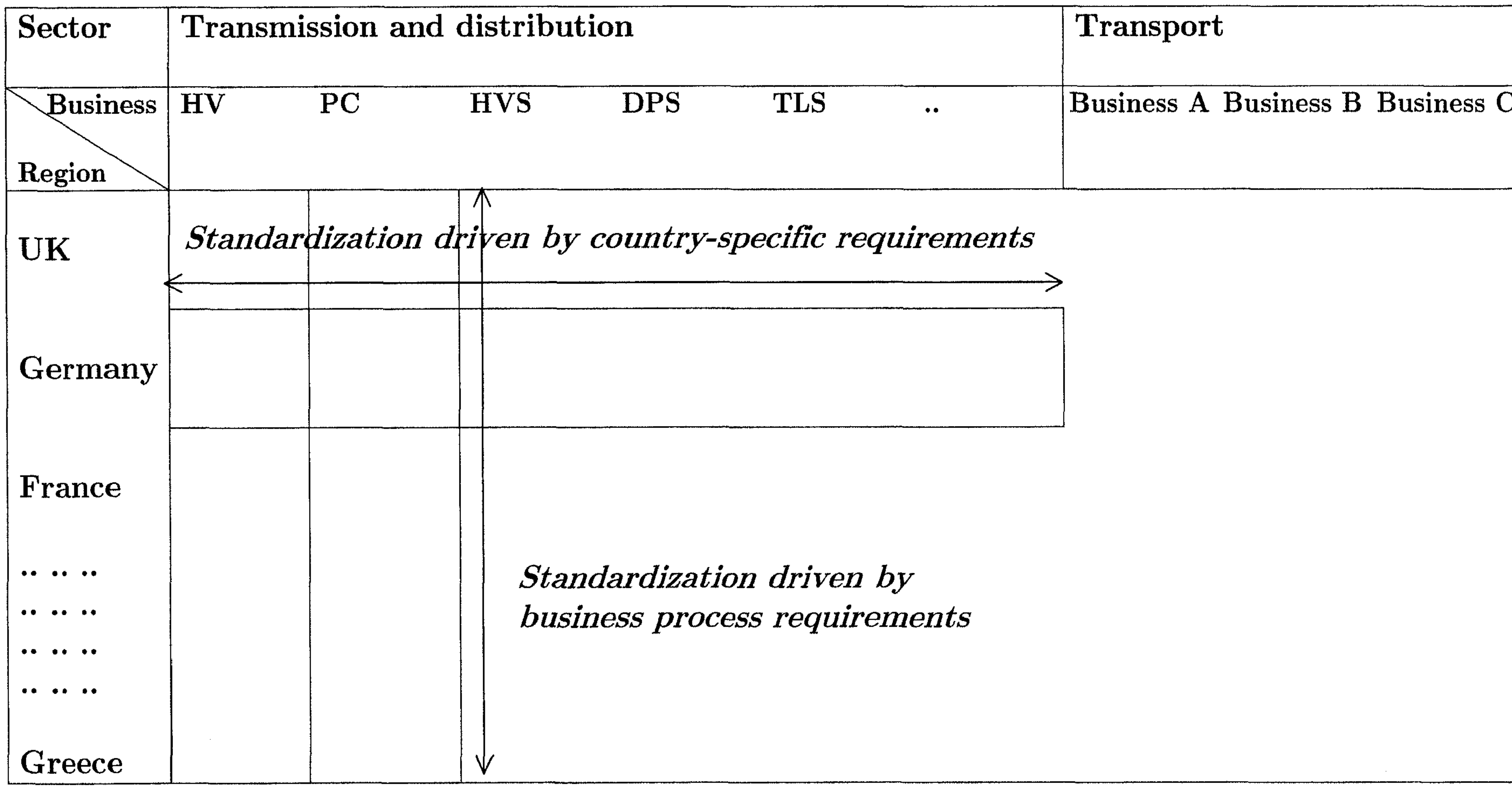

Figure 3: ERP standardization forces at Atom

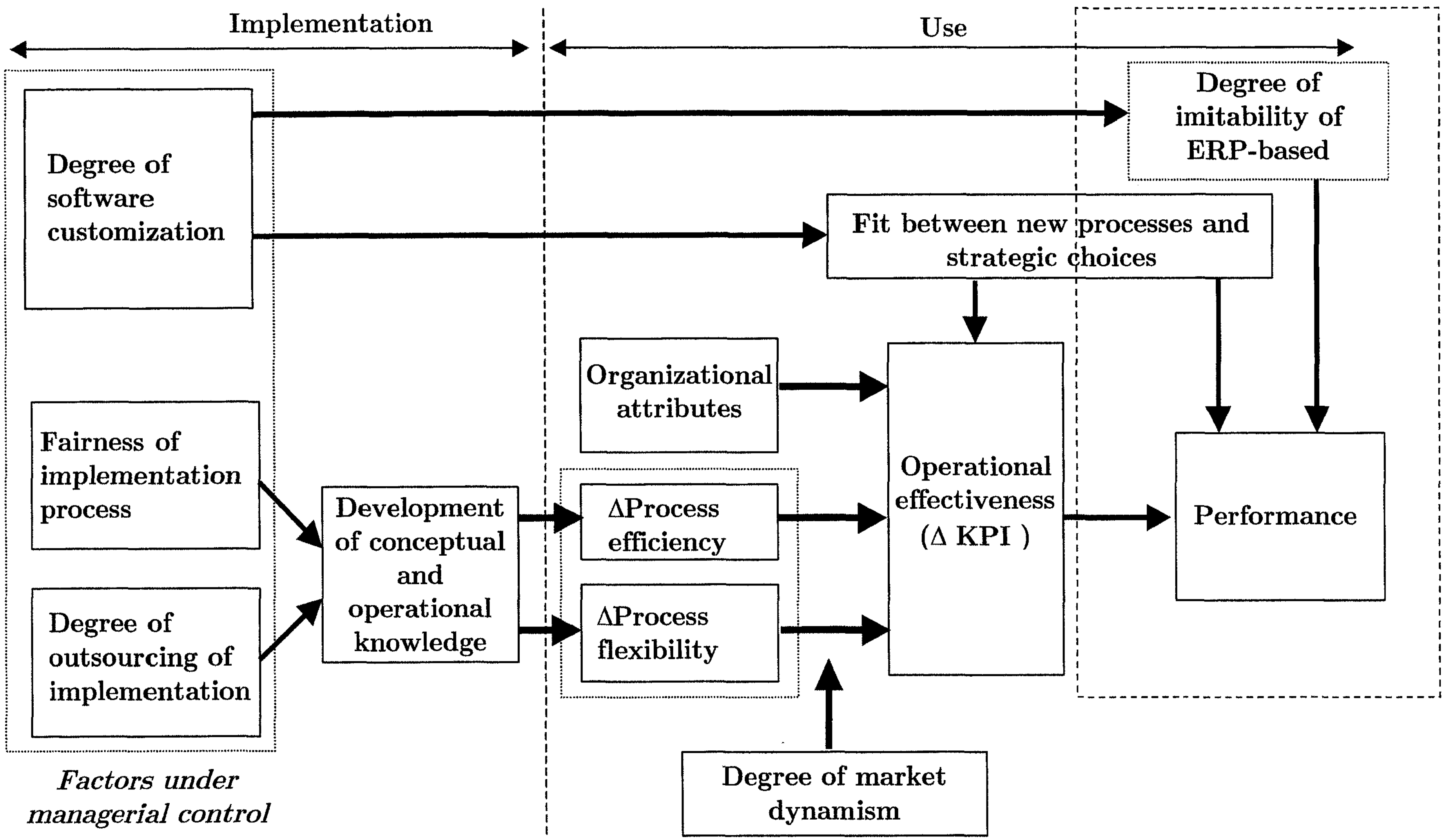

Figure 4: A general model of ERP-driven profitability

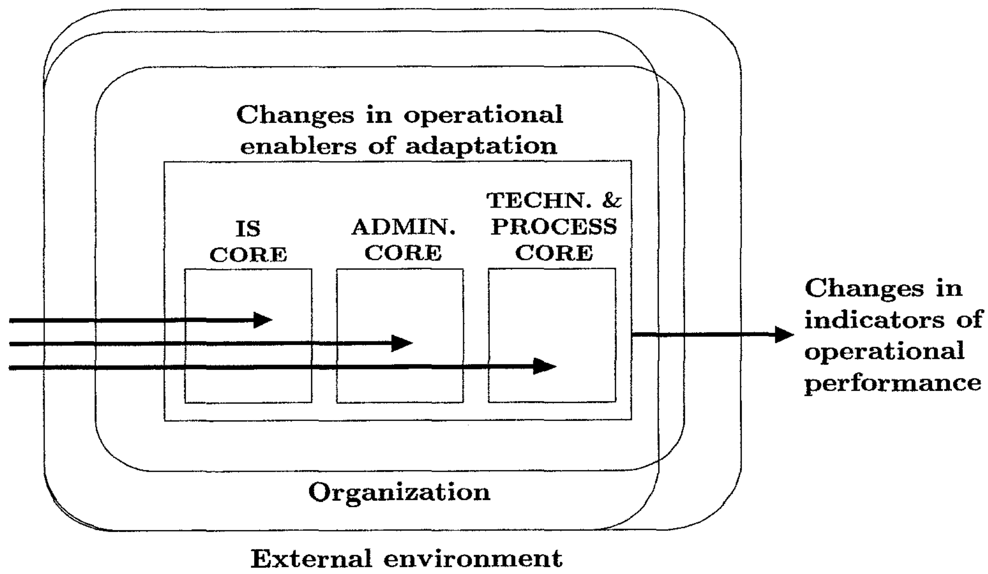

Figure 5: Impact of ERP adoption on organization's cores

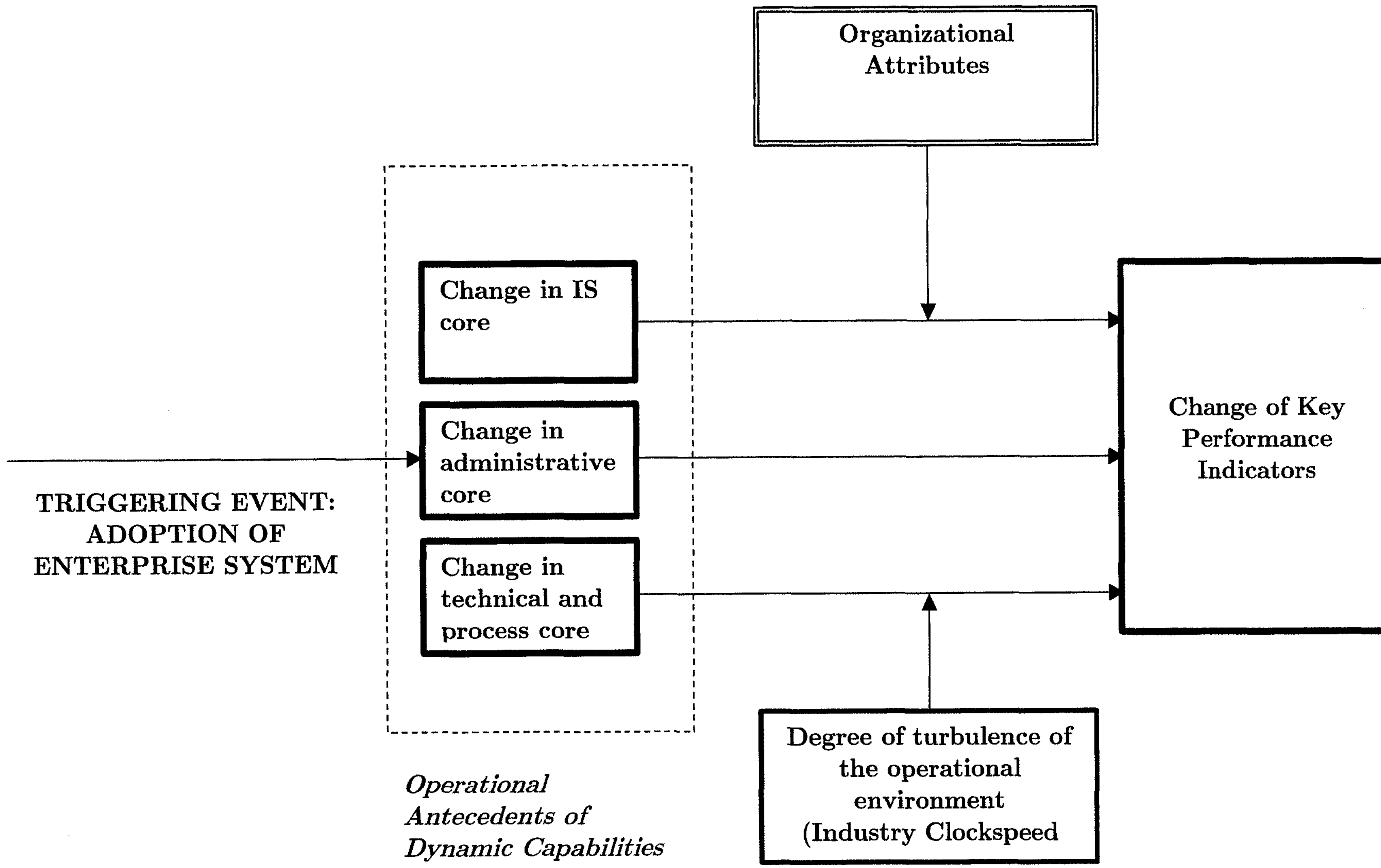

Figure 6: A contingency model of ERP-driven performance changes

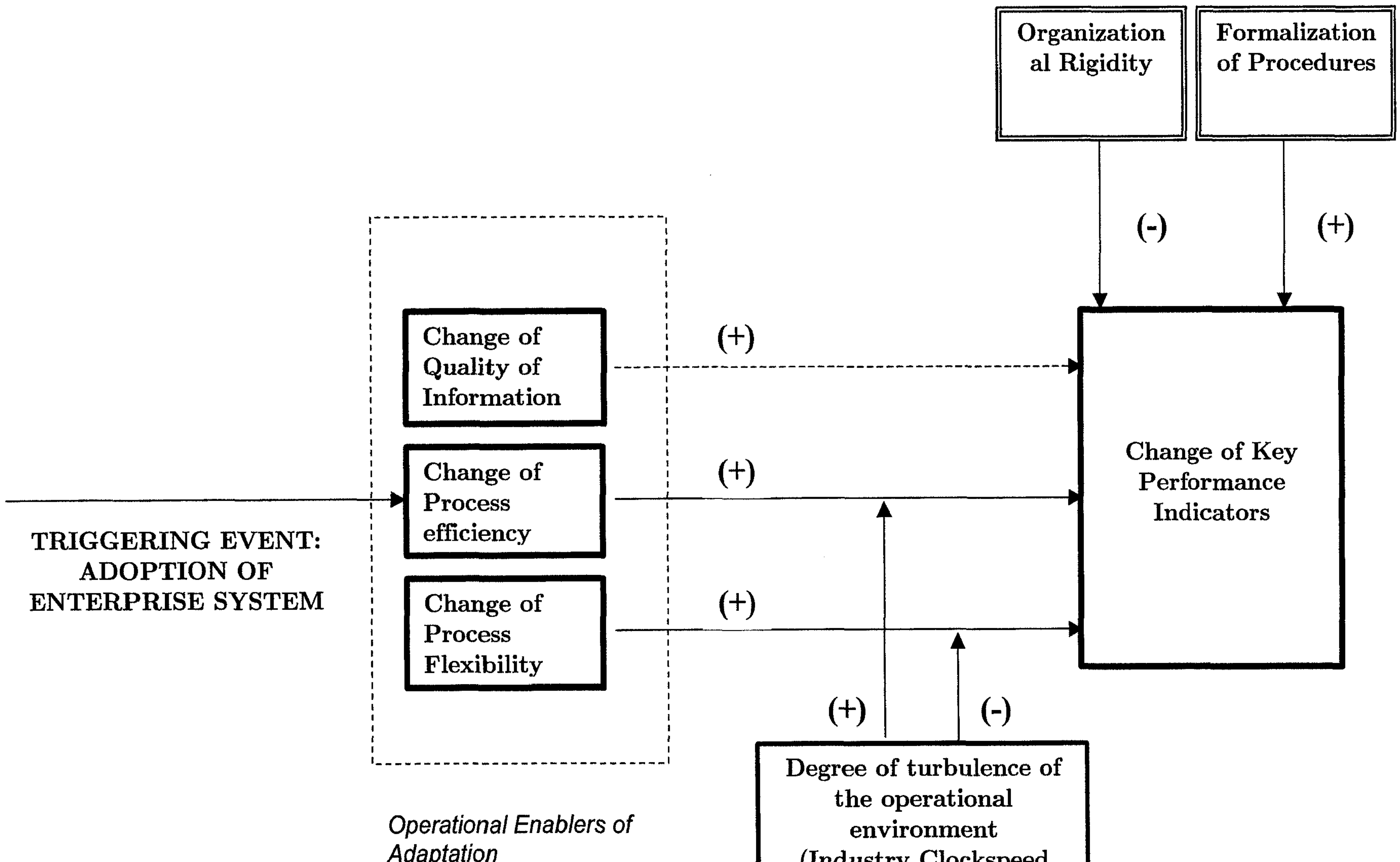

Figure 7: True direct and moderating effects of main predictors

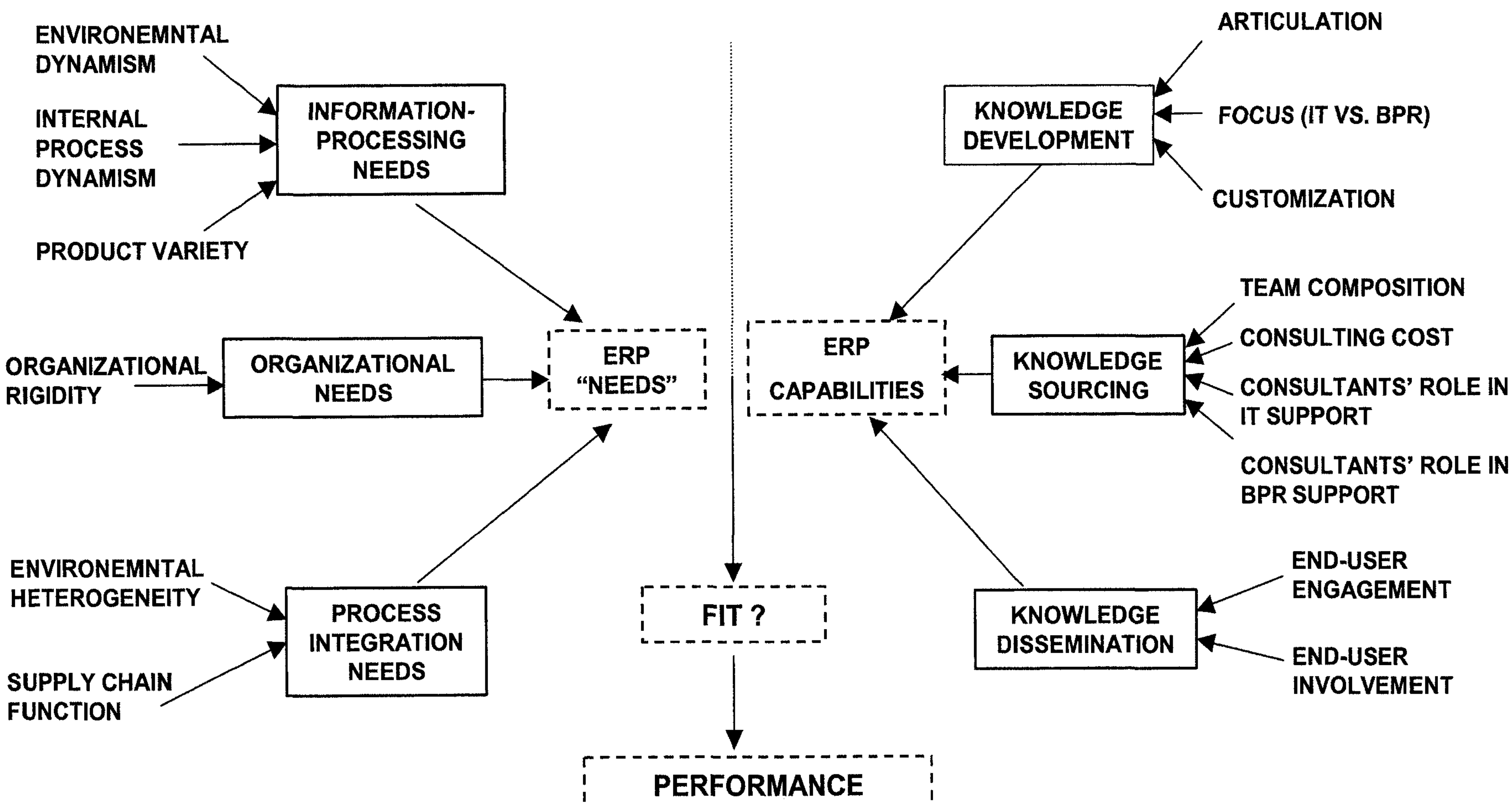

Figure 8: A conceptual model of fit between ERP needs and ERP capabilities

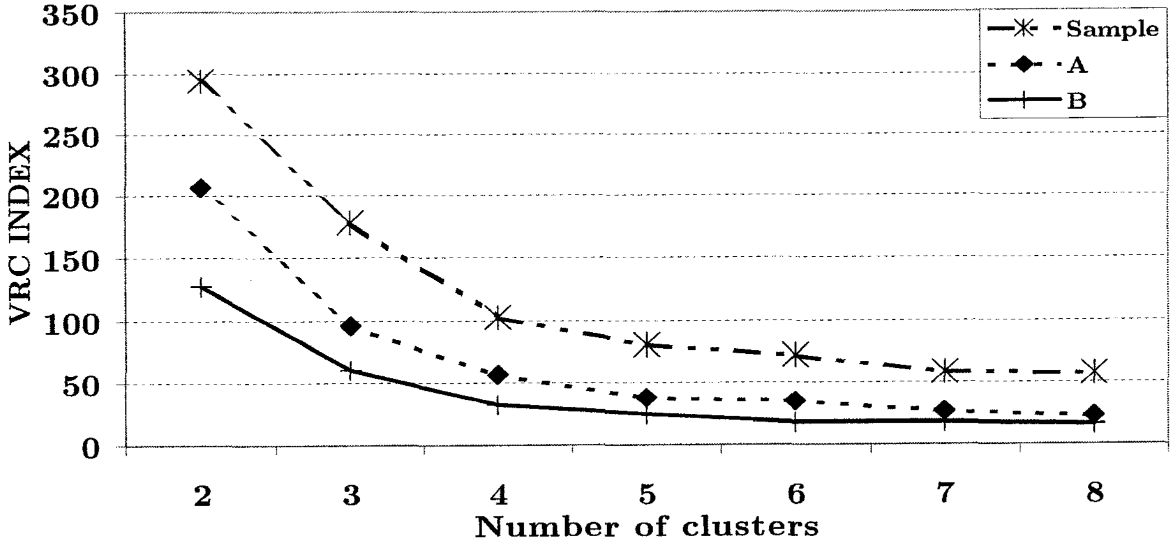

Figure 9: VRC index as a function of number of clusters

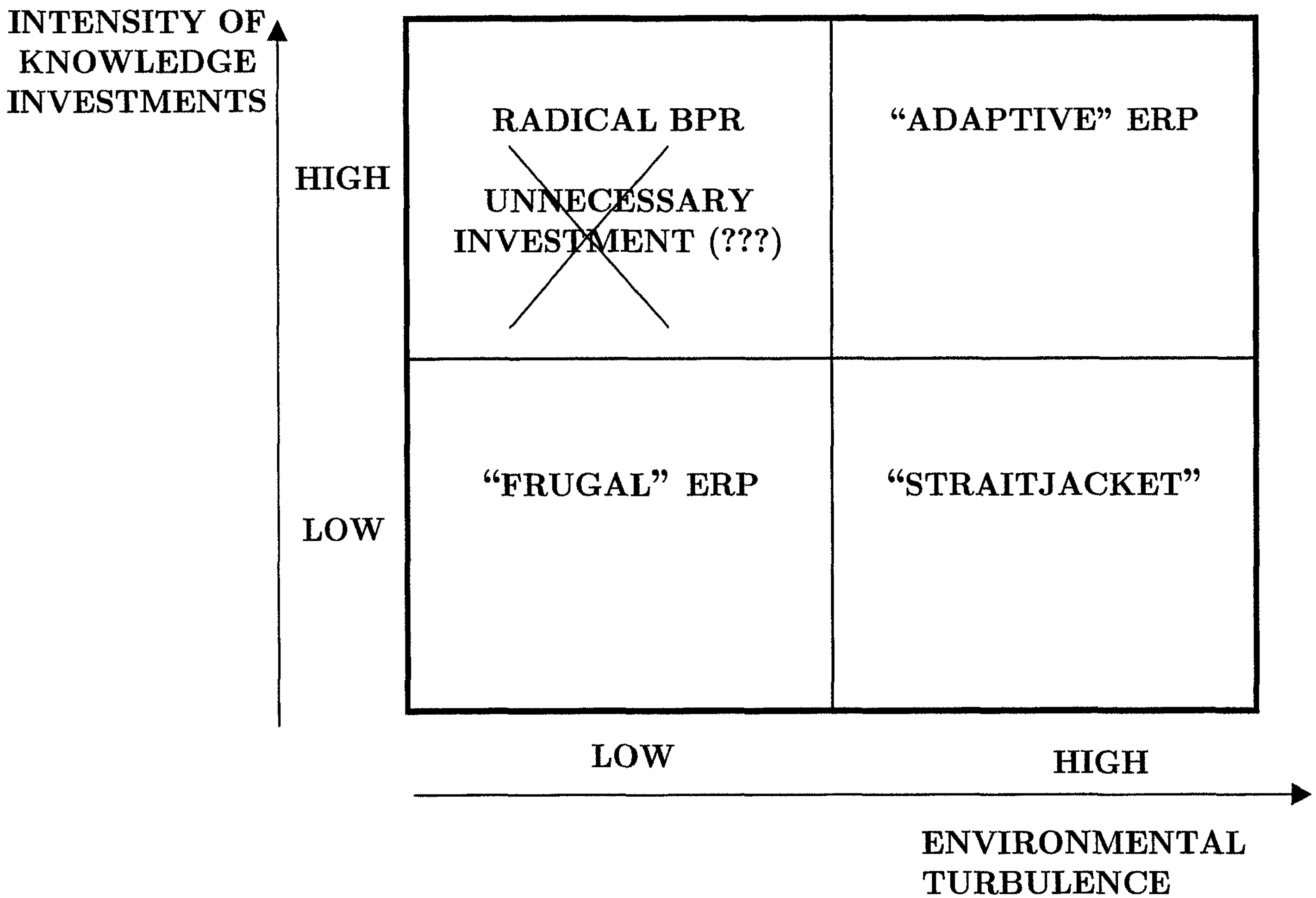

Figure 10: Four configurations of ERP adopters